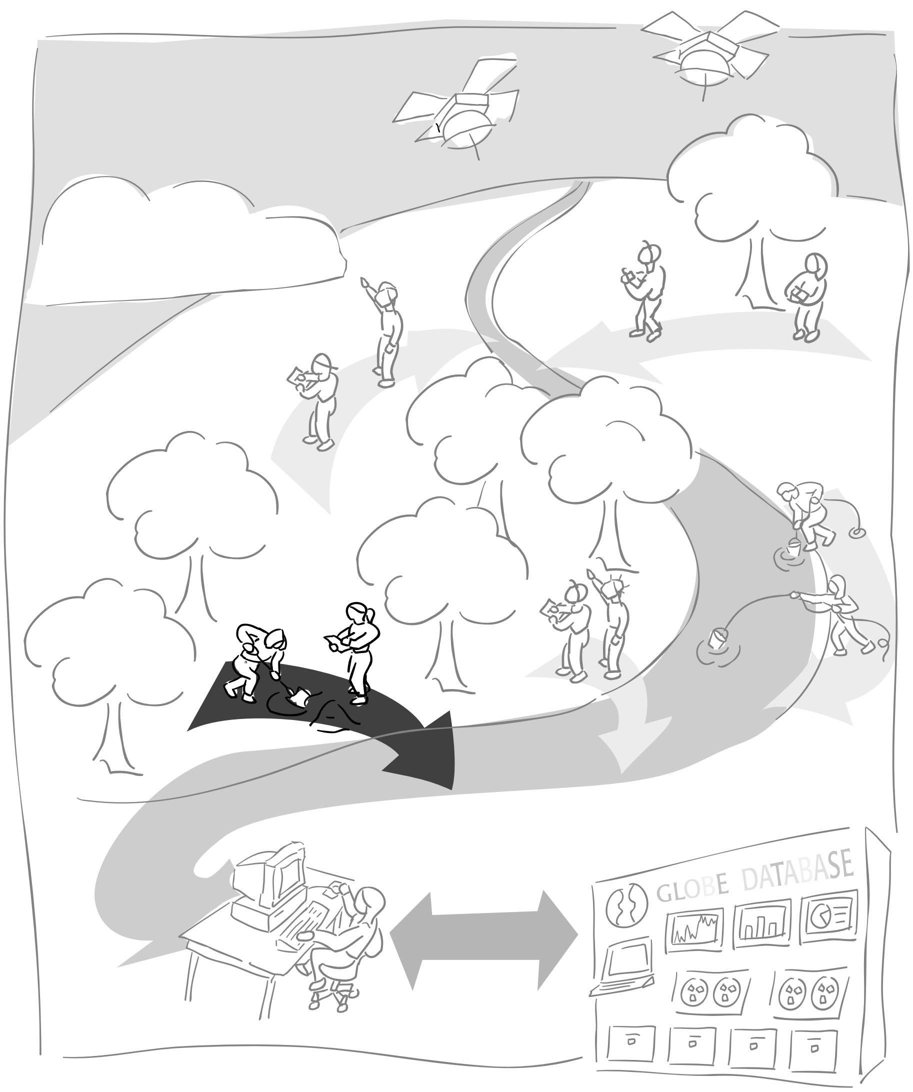
Soil Investigation



A GLOBE™ Learning Investigation

Soil Investigation at a Glance

Protocols

Measurements taken once at two or more Soil Characterization Sample Sites
- top and bottom depths for each horizon in the soil profile
- structure, color, consistence, texture
- bulk density, particle size distribution, pH, and fertility (N, P, K) of samples taken from each horizon
- soil infiltration
- surface slope (in degrees)

Measurements taken at the Soil Moisture Study Site:
- soil moisture, 12 times per year
- soil temperature, weekly
- diurnal variation of soil temperature, seasonally
- soil infiltration, seasonally

Suggested Sequence of Activities

Read *Welcome to the Soil Investigation*.
Copy and distribute to your students the scientists' letters and interviews.
Read the *Protocols* to learn precisely what is to be measured and how.
Read *The Learning Activities at a Glance* at the beginning of the *Learning Activities* section.
Do the first four activities before beginning the protocols.
Make copies of the data sheets in the *Appendix*.
Perform the *Soil Characterization Protocols*.
Perform the *Soil Moisture Protocol*.
Visit the GLOBE World Wide Web site with your students and review the data submission pages for Soils.
Submit your data to the GLOBE Student Data Server.
Do the remaining learning activities.

Special Notes

You may require help to dig your soil pit, if you choose to dig one.

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Appendix

Scientists' Letters to Students

Duplicate and distribute to students.

This investigation consists of two interrelated investigations. Soil Characterization, led by Dr. Elissa Levine, examines soil properties. Soil Moisture, led by Dr. Jim Washburne, examines the moisture in the soil.

Hello Students!

I am Elissa Levine and I am a Soil Scientist for the National Aeronautics and Space Administration (NASA). I am excited to be working with you.

People ask me, "Isn't soil just dirt? Who cares?" It's my favorite question. We take soils for granted, yet soils are among our most important natural resources. The ecosystem depends critically on soils. Soils allow water, energy and heat to flow through them, and they are essential for our food and clothing. We walk on soils, play on them, drive on them and construct homes, schools and buildings on them.

As a girl, I was fascinated by the color of soil, the way it felt, and all the rocks, roots and creatures living in it. As I grew up, I became concerned with feeding people and the proper use of our natural resources. So I studied soils.

What does a Soil Scientist do at NASA? I work at the Goddard Space Flight Center in Maryland. Our orbiting spacecraft carry sensors that send us images of the Earth, and I help to explain what the images reveal about the Earth's surface.

Together, we will determine what your soil looks like, why it looks that way, and how we can manage it for a healthy environment. You will closely examine soil samples from your study site.

Scientists will use your data to learn about the different soils across the Earth. Your data will help us to better interpret our satellite images and to better understand how systems interact on Earth and to predict what will happen to the soil in the future.

Have fun digging and exploring!

Elissa Levine

Dr. Elissa Levine
NASA/Goddard Space Flight Center
Greenbelt, Maryland, U.S.A.

Duplicate and distribute to students.

Dear Students,

Hi, my name is Jim Washburne. I am a research hydrologist at the University of Arizona in Tucson. Hydrology is the study of water and its movement through the atmosphere, soil and the underlying rocks. I am the scientist responsible for GLOBE soil moisture measurements.

When I was young, I was fascinated by how scientists discovered and tracked the movement of continents and the spreading of ocean floors from mid-ocean ridges. I feel the same level of excitement today in studying the Earth's water. New discoveries are being made daily but many questions remain unanswered.

People used to study the Earth piece by piece – looking at either soil, water, air, plants or animals. Now that we better realize how complex the Earth is, we know that it is important to study the whole system and the interconnections between the parts.

I am trying to understand how the water cycle works in dry areas of the world by asking questions like:

- When it rains, how much water remains in the soil and for how long?
- How does human activity affect the water cycle?
- How accurate are satellite data and can they be used in hydrologic models?

Scientists use sophisticated instruments and even satellites to measure soil moisture remotely. Only satellite data when linked with direct, long-term, hands-on ground observations can give us the valuable information we require. This is why we need your help in the field to make direct measurements of soil moisture. By monitoring your GLOBE sites, you will tell scientists what is actually happening on the ground.

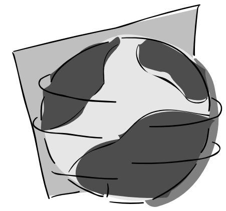
Each one of you can make a difference by making good observations and asking challenging questions. I look forward to working with you. Have fun exploring, measuring, and making sense of your data.

Sincerely,

Jim Washburne

Dr. James Washburne
Department of Hydrology and Water Resources
University of Arizona
Tucson, Arizona 85721-0011 USA
phone (520) 621-9944
fax: (520) 621-1422
email: jwash@hwr.arizona.edu

Meet Dr. Elissa Levine and Dr. Jim Washburne



Duplicate and distribute to students.

Dr. Levine: I'm a soil scientist for NASA's Goddard Space Flight Center in Greenbelt, Maryland. Goddard focuses on the Earth and Earth-orbiting satellites. I interpret images from the satellites that tell us about the environment. I also do soil modeling. We put all the soil information into a computer. We then factor in things like the type of vegetation and climate and write equations to describe how water moves through soil or how soils change over time. We try to predict what will happen.

Dr. Washburne: I'm a hydrologist at the University of Arizona. A hydrologist studies water. I'm studying the flows of water from one part of the planet to another. GLOBE fits into my work with NASA's Earth Observing System (EOS). Its goal is to launch the next generation of environmental resource satellites to collect data about the Earth. But as good as these satellites are, soil moisture is difficult to measure from space. There are really no good databases for regional or global soil moisture to check the satellite data.

GLOBE: *Soil is just dirt. Why is it important?*

Dr. Levine: My favorite question. Soils are one of the most important natural resources that we have. Every part of the ecosystem depends critically on soils. Soils filter water and remove its impurities. The food we eat, the clothes we wear, and many building materials all grow from the soil and depend on its conditions. Water and heat flow through it. It allows nutrients to be stored. Since the soil affects the entire ecosystem, I call it the great integrator.

Dr. Washburne: Soil moisture – the amount of water contained in the soil – is an important factor in determining the kinds of crops, lawns, shrubs and flowers we can grow. Scientists would like to know how soil moisture interacts with the atmosphere and climate.

GLOBE: *What questions are you trying to answer with the GLOBE data?*

Dr. Levine: What kinds of soils are there around the Earth? What are their properties? How do they relate to the other parts of the ecosystem?

GLOBE: *What kind of data do you want from GLOBE students?*

Dr. Levine: Students will examine samples of soil from their study site and study them in a variety of ways. I want them to become familiar with soil properties so we'll better understand how moisture flows in soil, how soil relates to vegetation, how it affects the climate, and so on. I'll put their data into my models.

Dr. Washburne: Students will learn how soil moisture varies by season throughout the world. To do that, we need as many observations as possible to compare with the satellite data and our computer models. Satellites, at best, can only measure soil moisture in the top five centimeters. We will use the student data to verify what the satellites measure with what's actually on the ground.

GLOBE: *Why do you need students to collect this data? Why can't you just get scientists to gather it?*

Dr. Levine: There aren't enough scientists. There are many different kinds of soil on the Earth. Most research has been in agricultural areas. But there are urban areas, forested areas, arid areas and many other places for which we have little data.

Dr. Washburne: When scientists do a careful study of soil moisture somewhere, that is only one measurement at one site at one time. GLOBE students represent a vast network of soil moisture and related observations that eclipses any past effort.

GLOBE: *Have students collected data before for soil investigations?*

Dr. Levine: Not at this level. Most work has been done by individual scientists, never by this great worldwide sampling effort.

Dr. Washburne: I'm confident students can do it. The soil-moisture observation is simple. You dig up some soil, weigh it, dry it, then weigh it again. The difference is how much water has been dried out of the soil.

GLOBE: *You are both involved with NASA, yet the common perception is that NASA explores space. Is it also involved in Earth exploration?*

Dr. Levine: Yes. NASA looks at Earth as a planet, just like any other planet. NASA's Mission to Planet Earth is one of its most important projects. Only by observing the Earth from space can you monitor its many ecosystems and study the interconnections between them.

GLOBE: *Tell us a little about yourselves. Where did you grow up and go to school?*

Dr. Levine: Long Island, in the suburbs of New York City. My parents used to take me to parks, caves and petrified forests in upstate New York, and I became interested in natural areas. I always had this fantasy to live in a cave or under a waterfall. That was the beginning. I liked math and science in school. In college in the early '70s, I studied psychology for a couple of years, but I got a strong idealistic desire to preserve nature and help feed people. So I went to an agricultural school where I became interested in soils. In the summers, I did soil mapping and conservation work. When I finished school there, I went for my Masters' and Ph.D. degrees. This is where I really began to explore soil profiles in different parts of the US and the world. I was fascinated by how each soil develops its own unique properties that determine how it can be used. As I learned more about soil properties and soil formation, I began to put it all together in mathematical models.

GLOBE: *We don't see enough women in science.*

Dr. Levine: I'm glad that you brought that up. In high school, I was interested in science. But I didn't really trust that I could do it.

GLOBE: *Because you were a woman?*

Dr. Levine: That's what I think. Most people around me are men, and my experience has shown that there is generally a difference in the way we think. I tend to see the big picture, while many men around me tend to focus better on the details. So together we complement each other. But we need more women in science because it's unbalanced now. We need to tie all these systems together.

GLOBE: *Were you discriminated against because you're a woman?*

Dr. Levine: In high school, I got As and Bs in science and math, but I didn't have much guidance from the people around me, or many role models to help me. I wanted to have a good career, but to also have a family. I learned that if I followed my heart, things will work out. I am now a scientist and I have two wonderful children. People in science who have families add a very positive dimension. A family gives you purpose. I'm concerned about the Earth because I want my children to have happy and healthy lives. You can have both a family and career.

GLOBE: *Are there many women in the field now?*

Dr. Levine: Yes, and more are entering the field. There is an organization called the Association of Women in Soil Science, and women get together at international soil-science meetings. We tend to have similar experiences.

GLOBE: *Where did you grow up, Dr. Washburne?*

Dr. Washburne: I was born in Denver, Colorado, and stayed in the state through high school. I spent a lot of time in the Colorado Rockies hiking and working on ranches. Like many states in the western U.S., Colorado is semi-arid and you usually have to irrigate crops or water lawns. So water's been an element in my life for a long time. My goal in college was to major in physics, but since I grew up in the Rocky Mountains, with their abundant outcroppings as testament to the great forces of nature, I was drawn into a geology major as well. In graduate school, I studied geophysics at Colorado School of Mines in Golden, Colorado. I learned to use electrical measurements to remotely sense below the surface of the Earth for mineral and oil deposits. After several good years, the exploration industry declined and I was laid off, I returned to school to get a Ph.D. in the exciting and interdisciplinary field of hydrology.

GLOBE: *When did you first become interested in science and why?*

Dr. Washburne: The methodology of science, of carefully studying something, is very satisfying to me. I have always enjoyed science and unraveling the relationships between the things around me, but it was not until I took my first physics class that I fully appreciated the simplicity and power science has to explain our universe. You will find that becoming a scientist requires a strong commitment. I find science satisfying because it helps to explain nature and is challenging - like an unfinished mystery.

GLOBE: *If there was one question that you could answer in your field, what would it be?*

Dr. Levine: Soils have different layers, colors, shapes and textures – all kinds of different things and different organisms living in them. How do they all fit together in this complex system?

Dr. Washburne: What will be our effect on the climate over the next hundred years? If the climate warms up, the hydrologic cycle might become more active, but we really do not have all the answers yet.

GLOBE: *What are the rewards of science?*

Dr. Washburne: I find all Earth science, particularly hydrology, to be very satisfying and valuable to society. What attracts many of us to science is not necessarily the global discoveries as much as the day-to-day discoveries, revelations, and satisfaction that the search and the sharing of what we know brings to us.

I'm also gratified that there are important social and policy issues that hinge on my work. My satisfaction comes from understanding something clearly, and it is amplified when you know this something has great ramifications. For instance, my study of soil moisture is part of a larger effort to improve the climate models scientists use to understand human impact on global temperature. The social and economic ramifications are enormous.

But everyday satisfactions are important, too. Knowing why the old farm road gets so slippery when moisture gets mixed in with the clay or understanding where the colors of the rainbow come from can be richly rewarding to you or me. Science is a process with many exciting (re)discoveries along the way that are new and meaningful to the individual. Don't forget to savor the small discoveries. They are as much the glue of the universe – the spice of life – as are all the grand old theories.

GLOBE: *Scientists all seem to have a healthy dose of curiosity. Is that something you identify with?*

Dr. Washburne: Definitely. It's important for scientists to ask questions. Scientists are no different from anyone else. I don't think there's anyone who can't become a scientist by applying themselves. In school, we are deluged with facts. From those facts, try to understand the fundamentals and apply them to issues that matter to you.

Despite all we do know, there's so much more to learn about the world and the way its elements interact. I think GLOBE students are lucky because they will be the ones to harvest the results of NASA's Mission to Planet Earth throughout their careers. It's very exciting that there's still so much to learn and understand about the world around us.

Dr. Levine: I know that I have a strong dose of curiosity. This curiosity is probably why scientists say: the more you learn, the more you know how little you know. I am especially curious about what new information about soils we are going to learn from the GLOBE student data.

GLOBE: Do you have international colleagues?

Dr. Levine: I do. Recently I was at a conference in China to study similar issues about soils that we're also studying in the U.S. I have also worked with people in Australia, Europe, Russia, South America and the deserts in Africa.

Dr. Washburne: I have colleagues in Europe and Latin America and have traveled to some far corners of the world. I am looking for collaborators from all over the world to work with GLOBE students and their observations.

GLOBE: When you were growing up, did you have heroes?

Dr. Washburne: I always wished I had grown up in Lewis and Clark's time or had been with Captain Cook in his voyage around the world. Even the simple mountain men were heroes to me. How exciting it would be to be among the first to explore previously uncharted territory, where every step you took would be a discovery unto itself.

GLOBE: What's a typical day like for you? Do you work in labs?

Dr. Levine: Although I am interested in field soils, much of my time is spent in front of a computer doing research, running models, writing and reading scientific articles, and answering email. When I do get to go in to the field, I go with a team of other scientists and we spend a week or two characterizing and monitoring different sites based on soils, vegetation, and climate. Then we bring samples back which are sent off to be analyzed. I use the data from the field work to test and create the models I use for my research.

Dr. Washburne: Surprisingly, I spend the majority of my time writing and reading about 40% and 10%, respectively during the average week. The 30% of my time I spend on the computer is divided between email, analysis, and programming. I would like to spend more time reading about what other people have done. That's important for scientists to do, and sometimes I only have time to skim abstracts. I spend ten percent of my day in meetings, talking with other scientists and devising strategies for various problems. If I get through a week when only 10% of my time is unclassified, then I am doing exceptionally well. What I like about my job is that every day is different.

GLOBE: *You said that students have not done this kind of work before. Is GLOBE unique?*

Dr. Levine: Oh, definitely. It's going to help us so much to understand soil properties. Having soils in grade school is great. It will help all people have a better

appreciation of the importance of soils. I'm excited that soils will be an important part of their Earth systems studies. It should have been there all the time.

GLOBE: *What do you hope students will learn in GLOBE?*

Dr. Washburne: I hope they will better observe and understand the environment around them and appreciate the need to support scientific research – particularly to learn how people and nature can live in greater harmony.

GLOBE: *Why should a student enter soil science today?*

Dr. Levine: Soils are critical for survival. We need young scientists who understand how soils fit into the rest of the ecosystem and help us maintain our standard of living and have a healthy Earth to live on.

GLOBE: *Why should a student today become a hydrologist?*

Dr. Washburne: Hydrology is exciting and has many specializations. A very important one is investigating and cleaning up our ground water. This will take a lot of work. The global hydrology I'm working on is also important. NASA's launch of a new generation of Earth resources satellites will definitely generate many questions to be solved by today's students for years to come.

GLOBE: *Any advice for students in general and young women in particular who might be interested in pursuing Earth science?*

Dr. Levine: My number one advice for all students is to go outside and explore natural areas that are nearby. Look at flowers, look at the ground, feel the soil under their feet, dig a hole, and look at what's there. Once students appreciate the ecosystem, a lot of their other classes in math and science, even history and language will make more sense. So that's number one: Get outside.

To women I would say, we need you. We need to take our place next to men. We have a very important role to play. Both men and women need to look at the Earth through a more holistic, nurturing type of approach. Women can do anything they choose to and do it really well.

Dr. Washburne: It is important not to be narrowly focused. I urge students to get a broad background in whatever they're doing. In global hydrology, it's essential to understand soils, remote sensing, the atmosphere, meteorology, and how trees and plants interact with water. It's very interdisciplinary. Computers are important, and mathematics is the foundation for a lot of our work. Do what you enjoy doing the most, and don't feel that all the questions have been answered or are going to be answered anytime soon. Speak up and ask questions, because fundamentally that's what we do: ask questions and look for their answers.

Introduction

Soil

The Big Picture

Soils are a thin layer, called the *pedosphere*, on top of most of Earth's land surfaces. This thin layer is a precious natural resource. Soils so deeply affect every other part of the ecosystem that they often are called the "great integrator." Soils hold nutrients and water for plants and animals. Water is filtered and cleansed as it flows through soils. Soils affect the chemistry of the water and the amount of water that returns to the atmosphere to form rain. The foods we eat and most of the materials we use for paper, buildings, and clothing are dependent on soils. Understanding soil is important for knowing where to build our houses, roads, buildings, and playgrounds as well. This investigation guides you through measurements of soil characteristics, soil moisture, infiltration, and soil temperature.

One of the most important characteristics of any soil is how much water it contains. Either in the form of a vapor or a liquid, water occupies about one-fourth of the volume of a productive soil. If the soil gets too dry and is not covered by vegetation, it blows away in the wind. Yet if there is too much water, the ground becomes soggy and cannot sustain many crops or, for that matter, the foundations of buildings. The rate at which water flows into or infiltrates the surface determines how much water will runoff during a rainstorm. Dry, porous soils can absorb large amounts of rain and protect us from flash floods. Soil that is nearly saturated with water or slow to take up water can heighten the likelihood of flooding.

All terrestrial life is directly or indirectly dependent on sufficient levels of water in the soil. Soil moisture combines with other properties of the land and climate to determine what kinds of vegetation grow. Soil acts as a sponge and holds water for uptake by the roots of plants. Some soils are more effective at this than others. For example, in deserts with sandy soil which does not hold water well, cacti store their own water, while other trees send roots deep in the soil to tap water buried tens of meters below the surface.

Soil temperature acts much the same way to influence all living organisms. Soil temperature changes more slowly than that of the atmosphere. In many temperate regions the surface soil freezes in winter, but below a certain depth, the ground never freezes and the temperature is almost constant throughout the year. In some cold climates, a permanent layer of ice called permafrost is found below the soil surface. Soil acts to insulate the deeper layers of soil and whatever lives in them from the extremes of temperature variation.

Figure SOIL-I-1

Soil Properties That Change Over Time

Properties that change over minutes, hours, or days	*Properties that change over months or years*	*Properties that change over hundreds and thousands of years*
temperature moisture content composition of air in soil pores	soil pH soil color soil structure soil organic matter content soil fertility microorganisms density	kinds of minerals particle size distribution horizon formation

Both the temperature and moisture of the soil near the surface affect the atmosphere as heat and water vapor are exchanged between the land surface and the air. These affects are smaller than those of oceans, seas, and large lakes, but at times they significantly influence the weather. Hurricanes have been found to intensify instead of losing strength when they pass over ground that is already saturated with water. Meteorologists have found that their forecasts are sometimes improved if they factor soil conditions into their calculations. How surface soil temperature and moisture respond to changes in the atmosphere depends upon the characteristics of the surface of the soil and those of the underlying soil profile. In GLOBE, student measurements include many of the physical and chemical properties of soil which will provide insights into the role soil plays in climate.

Soil Composition and Formation

Soils are composed of three main ingredients: minerals of different sizes; organic materials from the remains of dead plants and animals; and open space that can be filled with water and air. A good soil for growing most plants should have about 45% minerals (with a mixture of sand, silt and clay), 5% organic matter, 25% air, and 25% water.

Soils are dynamic and change over time. Some properties, such as temperature and water content (a measure of soil moisture) change very quickly (over minutes and hours). Others, such as mineral transformations, occur very slowly over hundreds or thousands of years.

Soil formation (*pedogenesis*) and the properties of the soil are the result of five key factors. These factors are:

1. parent material – The material from which the soil is formed. Soil parent material could be bedrock, organic material, an old soil surface, or a deposit from water, wind, glaciers, volcanoes, or material moving down a slope.

2. climate – Heat, rain, ice, snow, wind, sunshine, and other environmental forces break down the parent material and affect how fast or slow soil processes go.

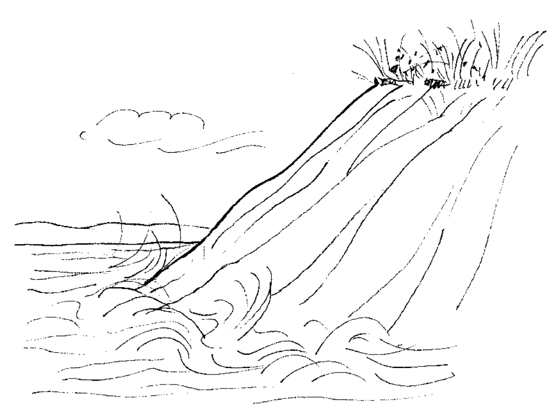
3. organisms – All plants and animals living in or on the soil (including micro-organisms and humans!). The amount of water and nutrients plants need affects the way soil forms. Animals living in the soil affect decomposition of waste materials and how soil materials will be moved around in the soil profile. The dead remains of plants and animals become *organic matter* which enriches the soil. The ways humans use soils affect soil formation.

4. topography – The location of a soil on a landscape can affect how the climatic processes impact it. Soils at the bottom of a hill will get more water than soils on the slopes, and soils on the slopes that directly face the sun will be drier than soils on slopes that do not.

5. time – All of the above factors assert themselves over time, often hundreds or thousands of years.

Soil Profiles

Due to the interaction of the five soil-forming factors, soils differ greatly. Each section of soil on a landscape has its own unique characteristics. The *face* of a soil, or the way it looks if you cut a section of it out of the ground, is called a *soil profile*, just like the profile of a person's face. When you learn to interpret it, the profile can tell you about the geology and climate history of the landscape over thousands of years, the archeological history of how humans used the soil, what the soil's properties are today, and the best way to use the soil. In a sense, each soil profile tells a story about the location where it is found.



To read some examples of these stories, see *Soils Around the World* at the end of this section.

Every soil profile is made up of layers called *soil horizons*. Soil horizons can be as thin as a few millimeters or thicker than a meter. You can identify the individual horizons because they will have different colors and different-shaped particles. They will feel different and have other properties that differ from those above or below them. Some soil horizons are the result of erosion. Soils are washed downstream and deposited over hundreds or thousands of years, creating extensive new layers of soil and gravel that can be identified in road cuts and trenches.

Soil scientists label horizons with a special code to identify them. Not all soils have the same horizons, and the horizons in your soil will depend on how it has formed. Some of the codes used to describe horizons are listed below:

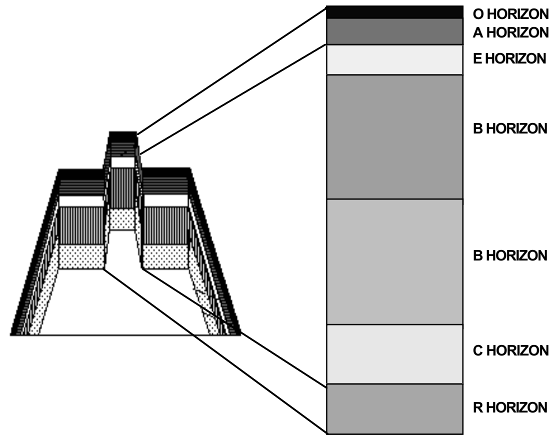
O Horizon

The O horizon is so named because it is made of *organic* material. This horizon is found on the soil surface and contains mostly organic material which has fallen from the vegetation above (such as leaves, logs, and twigs). It also includes the remains of animals and insects. Sometimes this organic material is decomposing so that it is difficult to recognize the leaves, twigs, or other material that were originally there. O horizons are most commonly found in forested areas. Agricultural fields, deserts, and grassy areas do not have O horizons in their soil profiles.

A Horizon

The A horizon is given its name because, like the first letter of the alphabet, it is the first mineral horizon of the soil and is commonly known as *topsoil*. The A horizon is made up mostly of mineral matter, although it may also include thoroughly decomposed organic material giving it a dark color. This horizon is usually darker than the horizon below it. In agricultural areas, the A horizon is the one that is tilled. When there has been much root decomposition and organic matter accumulation, the soil structure is granular. If compacted, the structure of the A horizon may be platy.

Figure SOIL-I-2



B Horizon

The B horizon is so named because it is generally the second major horizon in the profile, just as the letter B is the second letter of the alphabet. This horizon is primarily composed of parent material which has been severely weathered to the point that it is different in appearance. This horizon is commonly known as *subsoil*. Weathering causes changes in soil color, texture, and structure (which can be blocky or prismatic because of clay particles and chemical elements that move into the B horizon or columnar because of a high sodium content in dry regions). Also, the B horizon is called the accumulation (or *illuvial*) horizon because it is where the material leached from the A and E horizons has been deposited. Due to this accumulation, the B horizon may be rich in clays, organic matter, iron, aluminum, and other soil constituents that have moved in from above. Many B horizons have a reddish, yellowish brown, or tan color that is lighter than the A horizon. If the soil is saturated with water for long periods of time, the color may be gray or gray with red or orange streaks (mottles) through it.

Note: B Horizons may be very thick and may be broken down into two or more different layers. If there is more than one B horizon, they can be labeled as B1, B2, B3, etc. Look for changes in color, texture, structure, or consistence to help separate the B horizons from each other.

C Horizon

Like the letter C in the alphabet, the C horizon is usually the third major horizon in a soil profile. The C horizon is the most similar to the original parent material of the soil with no change in color, no structure formed (the soil is massive or single grained), no removal or deposition of soil materials through leaching, no coatings, no organic matter accumulation.

E Horizon

In certain soils (usually forested or under some wet conditions), an E horizon forms. The E horizon was named from the word *eluvial* meaning that clay, iron, aluminum, organic, and other minerals have been removed (leached) from it. It will appear white or lighter in color than the horizons above and below it. Many times, the soil structure is platy or single grained. This horizon is commonly found in forests where coniferous trees grow.

R Horizon

The R horizon represents a layer of rock that is sometimes found under the soil profile. The soil might have formed from this bedrock, or the soil parent material (such as *alluvial*, glacial or volcanic material) may have been deposited on top of the rock before the soil was formed.

Note: In a soil profile, you may not find all the horizons listed above in this table. For example, usually O and E horizons are found only in forested areas. If your soil profile is in an agricultural, desert, or grassy area, it will probably start with an A horizon and not have an E horizon at all. If the area has been eroded, your soil profile may start with a B horizon. Shallow soils, or soils that have not been extensively weathered may go from an A to a C horizon with no B horizon at all.

Your soil may have been altered by human activity at some time in the past. This could be a result of construction, when the builders placed soil *fill* from another location on this site, or when the horizons were not replaced in the same order as they were removed. Also, there may be more than one parent material from which your soil was formed. Parent material transported by water, wind, glaciers, volcanic activity, or landslides can be deposited on top of other parent material, or already existing soil profiles. This may become evident on the face of the soil profile by a sharp change in color, texture or other properties that indicate the soil did not all form from the same parent material.

Soils Around the World

The following figures illustrate a variety of soil profiles from around the world.

Figure SOIL-I-3: Grassland soils sampled in the southern part of Texas in the USA.

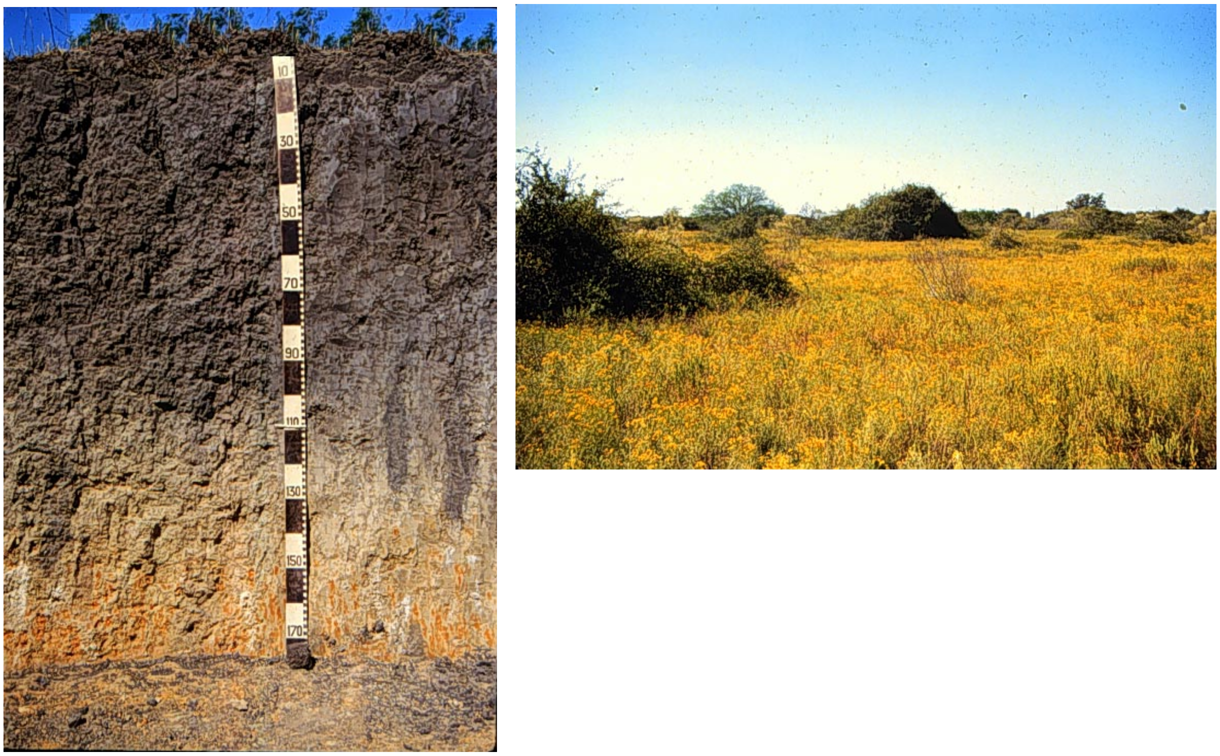
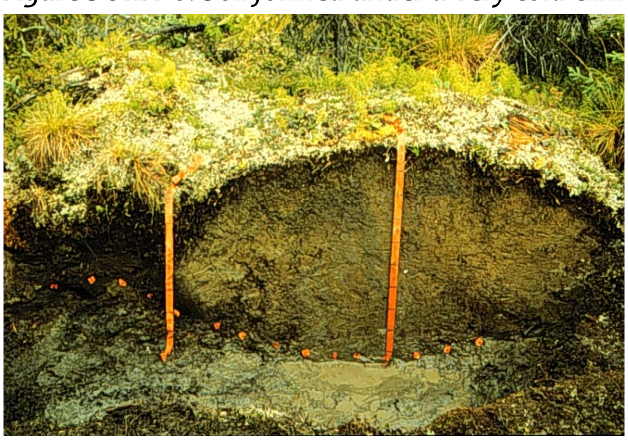


Figure SOIL-I-4: Soil formed under a forest in far eastern Russia, near the city of Magadan.

Figure SOIL-I-5: A tropical environment in Northern Queensland, Australia

Figure SOIL-I-6: Soil formed under a very cold climate near Inuvik in the Northwest Territory of Canada.



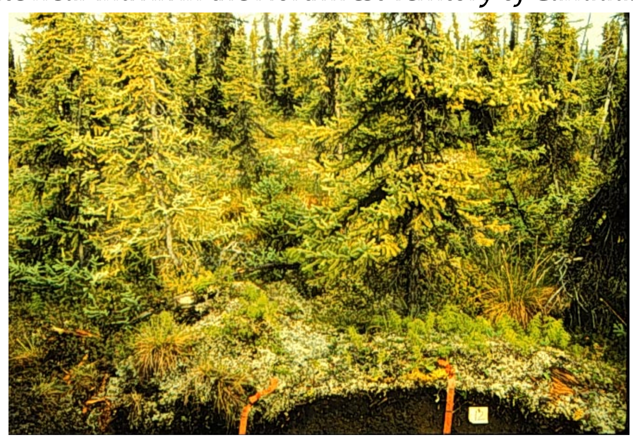


Figure SOIL-I-7: Soil formed under very dry or arid conditions in New Mexico, USA.

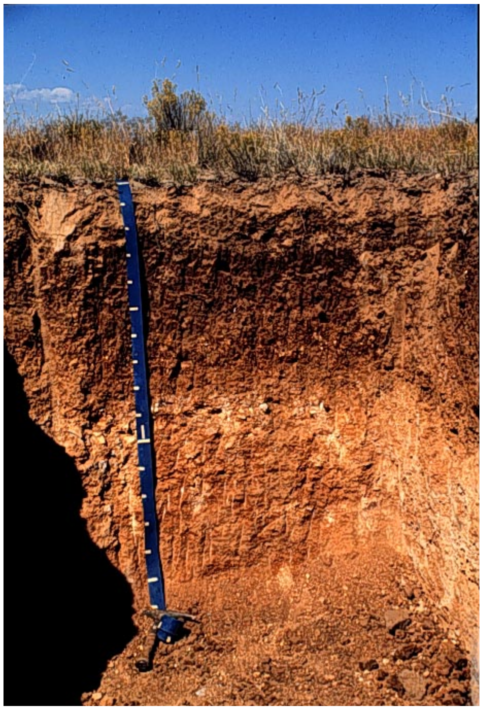


Figure SOIL-I-8: Wet soil sampled in Louisiana, USA

Dr. John Kimble and Sharon Waltman of the USDA Natural Resources Conservation Service, National Soil Survey Center, Lincoln, Nebraska provided the photographs shown here.

Overview of the Measurements

Soil Characterization

In the field, soil horizons can be distinguished from each other within a soil profile by differences in their structure, color, consistence, texture, and amount of free carbonates. When samples are taken back to the classroom or laboratory, measurements of soil characteristics such as bulk density, particle size distribution, pH, and soil fertility can also be different from one horizon to another.

Structure:

Structure refers to the natural shape of groups of soil particles or aggregates (*peds*) in the soil. The structure affects how big the spaces will be in the soil through which roots, air, and water may move.

Color:

The color of the soil changes depending on how much organic matter is present and the kinds of minerals it contains (such as iron which usually creates a red color, or calcium carbonate which colors the soil white in dry areas). Soil color also differs depending upon how wet or dry the soil sample is and can indicate if the soil has been saturated with water.

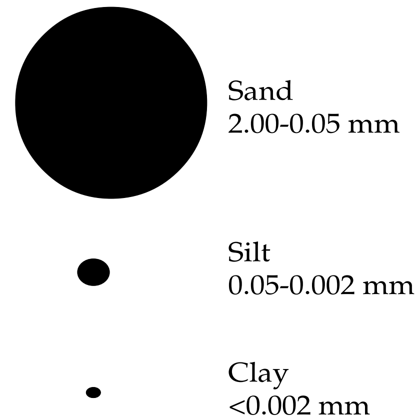
Consistence:

Consistence relates to the firmness of the individual *peds* and how easily they break apart. A soil with firm consistence will be harder for roots, shovels, or plows to move through than a soil with *friable* consistence.

Texture:

The texture is how the soil feels and is determined by the amount of sand, silt, and clay particles in the soil, each of which is a different size.

Human hands are sensitive to this difference in size of soil particles, so we are able to determine the texture or “feel” of the soil. Sand is the largest particle size group, and feels gritty to touch. Silt is the next size group, and feels smooth or *floury*. Clay is the smallest size group, and feels sticky and hard to squeeze. The actual amount of sand, silt, and clay size particles in a soil sample is called the *particle size distribution* and can be measured in the laboratory or classroom.



The relative (not the actual) size of sand, silt, and clay particles.

Figure SOIL-I-9

Carbonates:

Free carbonates are materials that coat soil particles in soils that are above pH 7, especially in arid or semi-arid climates. Carbonates usually have a white color, and can be scratched easily with a fingernail. They are salts of calcium or other elements that accumulate in areas where there is not extensive weathering from water. Also, carbonates can come from the parent material (e.g. limestone), can be caused by additions of carbonates to the soil, or can be the result of carbonate formation within the soil. Sometimes in dry climates, the carbonates can form a very hard and dense horizon which is similar to cement and will not allow plant roots to grow through it.

In GLOBE, this test is performed by squirting vinegar on the soil. If carbonates are present, there will be a chemical reaction between the vinegar, which is an acid, and the carbonates, which are bases, to produce carbon dioxide. When carbon dioxide is produced, it bubbles or *effervesces*. The more carbonates that are present, the more bubbles or *effervescence* you will observe.

Bulk Density:

Soil bulk density is a measurement of how tightly packed or dense the soil is. It is determined by measuring the weight of dry soil in a unit of volume (g/cm^3). How dense the soil sample is depends on the structure (shape) of the soil peds, how many spaces (pores) are in the sample, how tightly they are packed, and also the composition of the solid material. Soils made of minerals (sand, silt, and clay) will have a different bulk density than soils made of organic material. In general the bulk density of soils can range from 0.5 g/cm^3 in soils with many spaces, to as high as 2.0 g/cm^3 or greater in very compact horizons.

Knowing the bulk density of a soil is important for many reasons. Bulk density can give us information about the porosity (the proportion of the soil volume that is pore spaces) of a sample. This helps determine how much air or water can be stored or moved through the soil. Bulk density also indicates how tightly soil particles are packed together and if it will be difficult or easy for roots to grow or shovels to penetrate into and through a soil horizon. Bulk density is also used in converting between weight and volume for a soil sample. If we know the weight of a soil sample, we can calculate its volume by dividing the sample weight by the bulk density of the soil. If we know the volume of a soil sample, we can determine its weight by multiplying the sample volume by the bulk density of the soil.

Particle Size Distribution:

The amount of each particle size group (sand, silt, or clay) in the soil is called the soil particle-size distribution. Knowing the particle size distribution of a soil sample helps us understand many soil properties including how much water, heat, and nutrients the soil will hold, how fast water and heat will move through the soil, and what kind of structure and consistence will form.

The distribution of sand, silt, and clay in your sample will be determined by a settling measurement using an instrument called a *hydrometer*. The hydrometer is used to measure the amount of soil that stays in suspension after some of the soil has settled to the bottom of the cylinder.

Sand is the largest soil particle size group, silt is intermediate in size, and clay is the smallest. See Figure SOIL-I-9. There is disagreement in the scientific community about the exact size ranges used to distinguish sand from silt. For GLOBE, we will be measuring sand and silt based on 2 different size definitions:

1. The US Department of Agriculture (USDA) defines the size of sand as 2.0 - 0.05 mm, and the size of silt as 0.05 - 0.002 mm.
2. The International Soil Science Society (ISSS) defines the size of sand as 2.0 - 0.02 mm, and the size of silt as 0.02 - 0.002 mm.

GLOBE students will find the silt and sand amounts for both of these definitions so that our data can be used by scientists world wide.

Clays are the smallest particle size group and are defined by both organizations as being smaller than 0.002 mm. Particles greater than 2 mm are called stones or gravels and are not considered to be soil material.

Heavy, large particles settle first, so when a soil sample is stirred or shaken in a 500 mL cylinder, sand particles (according to the USDA definition) settle to the bottom of the cylinder after 2 minutes, while the clay and silt size particles stay in suspension. After 12 minutes, the sand (according to the ISSS definition) has settled, leaving the clay and silt particles in suspension. After 24 hours, the silt particles have settled, leaving only the clay in suspension.

pH:

The pH of a soil horizon (how acidic or basic the soil is) can be measured in the laboratory or classroom. The pH influences what can grow in the soil and is the product of the kind of parent material, the chemical nature of the rain and other water entering the soil, land management practices, and the activities of organisms (plants, animals, fungi, protists, and monera) living in the soil. For example, needles from pine trees are high in acids, and as they decay over time, they lower the pH of the soil. Soil pH is an indication of its chemistry and fertility. Just like the pH of water, the pH of soil is on the same logarithmic scale (see the *Introduction* of the *Hydrology Investigation* for a description of pH). It is important to know the pH of the soil because it affects the activity of the chemical elements in the soil, and so affects many soil properties. Different plants grow best at different pH values. Farmers will add *amendments* like calcium carbonate or calcium sulfate to change the pH of the soil depending on the kind of plants they want to grow. The pH of the soil also may affect the pH of ground water or of a nearby water body such as a stream or lake.

Fertility:

The fertility of a soil is determined by how many nutrients it has stored. Nitrogen (N) in the form of nitrate, phosphorus (P), and potassium (K) are three soil nutrients important for the growth of plants, and need to be maintained in the soil at a suitable level. Each also has the potential to leach from the soil into groundwater. By testing the soil for N, P, and K, we can determine how much of each is present in the soil horizons at your sample sites. Soil fertility information can help to explain why and how well certain plants grow at a Soil Characterization Sample Site, and also can be related to the water chemistry you will be measuring in the *Hydrology Investigation*.

Sampling Strategy

The protocols for Soil Characterization should be done once at each site where soil affects another GLOBE measurement. The two highest priority sites are within the Biology Study Site and the Soil Moisture Study Site. The protocols are divided between field and classroom activities. In the field, students describe and sample soil. For this, a hole is dug either with a shovel or an auger. Obtaining a soil profile one meter deep is desired, but an option is provided to sample the top 10 cm of soil when obtaining a 1 m profile is not possible. All students will describe the soil, take samples back to the classroom, dry and sieve the samples, determine the bulk density, and measure them for pH, nitrate, phosphorus, and potassium (N, P, K), and soil particle-size distribution. A measurement of surface infiltration rate should be taken as well.

Soil Moisture

Students should measure soil moisture at least twelve times every year at regular intervals. The choice of whether to take weekly measurements for 12 weeks, monthly measurements throughout the year, or 12 measurements at intervals of two or three weeks is left to GLOBE teachers and students. Different sampling patterns will provide data that are used by scientists in different ways and will show students different aspects of the variations in soil conditions. Measurements will be more interesting to students if they observe significant changes. Generally, soil moisture conditions will change most rapidly in early summer or during the transitions between the wet and dry seasons. Teachers and students should choose a sampling strategy which works well in the context of their school and which will result in 12 measurements being taken.

Any one of three sampling strategies can be chosen to match the capabilities of the students and the situation in your school. Again, different sampling strategies will produce data that will be used in different ways and will illustrate different aspects of soil moisture variation. A simple drying and weighing procedure is used to determine the soil water content of the soil samples in all three strategies.

In the easiest strategy, students sample soils near the surface at 0 - 5 cm, which is as deep as soil-moisture sensors on satellites penetrate the ground, and at 10 cm. Three samples are taken at each depth to provide a good check on data quality for a single location. In a second strategy, students take samples of the soil from a depth of 0 - 5 cm, every 5 m along a 50 m transect. This provides good information on local variations and a better characterization of an extended area. Three samples are taken at one location along the transect to check data quality. With both these sampling strategies, since students and satellites observe soil moisture near the surface, the two sets of measurements can be compared. The GLOBE data can be used to help calibrate, validate, or interpret the data from satellite sensors or aircraft versions of them. In a final strategy, samples are collected at five depths —

0-5, 10, 30, 60, and 90 cm. This strategy provides insight on how water moves through the soil column and provides data that better relate to the uptake of water by plants.

Students collect their soil moisture samples, place them in labeled soil sample containers and weigh them. Then, the samples are dried in a low-temperature oven (75 - 105 C) until all water is removed and the samples are weighed again. The difference in the weights before and after drying equals the amount of water that was in the soil. Scientists call this the *gravimetric* technique, which means a measurement by weight. The ratio of the weight of the water to the weight of the dry soil is called the *soil water content*. Note that this is not a percentage, since you do not divide by the total wet weight. The dry weight is an indication of the size of the soil sample. It is used because bulk density is usually a constant characteristic of a soil. When you divide the weight of the water by the dry soil weight, you get a number (soil water content) which can be compared with your measurements on other days even though the size of the soil samples may vary from one day to the next.

Soil water content typically ranges between 0.05 and 0.40 g/g. Often these values are multiplied by 100, and that is the convention we ask GLOBE students to follow. Even desert soils retain a small amount of water, although surface soils can fall below 0.05 g/g. Organic-rich soils, peat, and some clays can absorb large amounts of water, so it is possible to measure values above 0.40 g/g.

Infiltration

Infiltration, the rate water flows into the ground, is an important hydrologic property of soil. Scientists need this information to predict and model how much precipitation runs off or is stored by the soil. Infiltration rate depends upon many factors: soil structure, soil texture, bulk density, soil water content, and organic matter in the soil. Infiltration rates vary from less than 20 mm/hr for clays and compacted soil to 60 mm/min for loose, dry sand.

Infiltration should be measured at least three times each year at your Soil Moisture Study Site and once at each Soil Characterization Sample Site. A simple device called a double ring infiltrometer, made from two concentric cans of different diameters, will be used. Because infiltration varies with soil moisture, which changes with time, students will make one to nine measurements of infiltration over a 45 minute period. These observations should be taken on days when students are also taking soil moisture samples. Because infiltration rate can change by orders of magnitude due to animal or plant disturbances, students will take measurements of infiltration on a given day at each of three locations within 2 meters of one another.

Soil Temperature

Soil temperature measurements are related to the maximum and minimum daily temperatures measured in the *Atmosphere Investigation*. Students should gain useful insights by comparing the air temperatures with these observations as well as with the surface water temperature and precipitation measurements.

Soil temperature is measured at the Soil Moisture Study Site which should be within 100 m of the Atmosphere Study Site. If your school is not taking soil moisture measurements, take soil temperature measurements within 10 m of the Atmosphere Study Site. Measurements are taken at depths of 5 cm and 10 cm and provide data directly related to the measurement of near-surface soil water content at the site. Soil temperature should be measured weekly throughout the year. In addition, every three months on two consecutive days, students should take measurements at roughly two hour intervals throughout the day to reveal how near surface soil temperature varies with time of day at the study site.

Preparing for the Field

Soil Moisture Sampling Strategies and Site Layout

All Soil Moisture Study Sites should be located in the open, away from buildings, overhanging trees, and roads. The sites should not be irrigated. It is highly desirable that the Soil Moisture and Atmosphere Study Sites be within 100 m of one another so that their data can be interrelated and combined to obtain a more comprehensive picture of the environment near each GLOBE school.

The layouts for the three sampling strategies to be used in soil moisture measurement are summarized in the following sections.

The Star

Students collect soil-moisture samples at two depths close to the surface. Over the 12 different measurement days, the samples will be taken in a star pattern with a two meter diameter.

The Transect

Students collect eleven soil samples along a transect. These measurements are particularly helpful for comparison with satellite imagery. The transect is a straight line 50 meters long across an open area. Students measure soil moisture every five meters along this line. At one location along the transect, three samples are taken within 25 cm of one another to assist in checking data quality.

Depth Profile

Students take soil moisture measurements from samples cored out of the ground at five different depths — 0-5, 10, 30, 60, and 90 cm — using an auger.

An *Optional Gypsum Block Soil Moisture Protocol* for measuring soil water content, that is only recommended for advanced students, is given as well. Gypsum blocks are placed in the soil at four depths — 10, 30, 60, and 90 cm. — and students electronically monitor the moisture in the gypsum by determining how well the blocks conduct electricity. These measurements can be most directly related to the *Atmosphere Investigation* observations as they are taken daily. The gravimetric technique for determining soil moisture is used in conjunction with this optional protocol to calibrate the gypsum block readings.

Integrating with Other GLOBE Investigations

This investigation introduces students to rich connections between the soil and the surrounding land, water, and atmosphere. Placing your data collection stations in close proximity to each other will help you study interactions between the observed parameters. Some interesting comparisons are possible when you:

- locate a Soil Characterization Sample Site at the Land Cover/Biology or Soil Moisture Study Sites or at Quantitative Land Cover Sample Sites;
- do the introductory Hydrology activities along with the soil characterization and soil moisture activities; and
- take the soil moisture measurements near the Atmosphere Study Site.

Time Considerations

Spring and fall are usually the best times to study soil moisture near the surface or in depth profiles because the ground is less likely to be frozen or too dry. The activities should be done when students can observe the greatest contrasts.

The day after a rain is ideal for taking a soil moisture walk to observe ponded water, moisture under ground litter, dry and sunny spots, muddy depressions, and the soil beneath a canopy of trees or shrubs.

Educational Activities

Student Learning Goals

The soil system provides a natural laboratory for integrating many science activities. Students will develop an understanding of soil science, geology, biology, and ecology by studying the origin of their soil profile, the profiles of other soils, and how soils are affected over time by climate, vegetation type, parent material, and land use.

Students will understand the role of heat, water, and chemical constituents during soil formation (pedogenesis) and on the soil within their study site. Activities in these areas will provide a natural background for studying chemistry and physics.

Students will learn about soil moisture and temperature and their importance in local and global hydrologic, carbon, and energy cycles. The challenges of using remote sensing to observe the way soils affect regional and global processes will be introduced. Modeling techniques to predict soil properties and ecosystem parameters will also be included.

Students will develop observational skills by identifying soil properties and learning to identify how the interaction of climate, topography, biology, parent material (geology), and time form different types of soils. They will enhance their field skills in taking measurements properly, handling samples, and taking notes.

Students will become familiar with terminology, nomenclature, and methods that scientists use so that students and scientists can communicate with each other.

In addition, students will learn chemistry, physics, and biology concepts, and use math to visualize and model soil and related water properties and processes. Statistics and graphing will also be important to analyze findings.

Student Assessment

To assess your students' learning over the course of this investigation, we recommend that you evaluate students based on their:

Critical Thinking Skills

- Clear understanding and comprehension of concepts: Challenge their comprehension by presenting them with other possible scientific issues for inquiry. How well do they formulate questions, hypotheses, and methodologies to study their problems? Are their interpretations and conclusions thoughtful? In addition, are they critically reviewing information by challenging statements made by scientists, other students, and the teacher? They should be encouraged to question and ask for statements to be clearly explained. This will help create a real scientific community within the classroom that respects everyone's opinions and concerns.
- Observations and record keeping: Accuracy is essential for validation of research. Student observations should take into consideration issues that can compromise data such as sloppy methodology, inadequate sampling, and imprecise record keeping. However, mistakes are part of science. Students must understand that mistakes must be acknowledged in order to correct them. Even when results do not seem to be accurate, it is important that they are reported. Sometimes, even seeing nothing is an important observation. Making up data is lying and will only grow into a bigger problem later.
- Organization of scientific data: Questions at issue should be presented clearly, and pursuit of research and data must be organized to support these questions. Students must be able to judge what is adequate methodology to use in pursuing answers. Students must be able to interpret data to ensure the soundness of their conclusions.

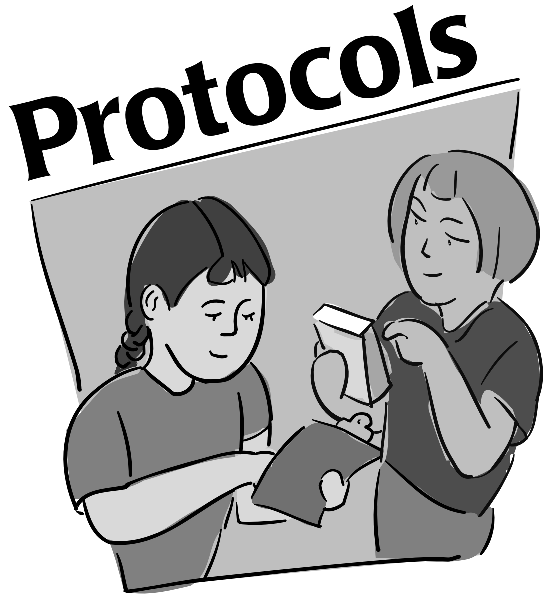
Communication Skills

The purpose of context-based learning is to introduce students to real life situations. Such an approach stresses the importance of communicating with others. Students should be able to communicate information, both verbal and written, in informal and formal settings. Informal settings of the classroom are used to hone their critical thinking skills and their ability to work cooperatively on common goals. Students should be able to work cooperatively with their peers to improve the quality of their investigations. They should be able (at the intermediate and advanced levels) to develop group assignments and tasks directed at achieving the goals of their investigations. This should be evident through conversation and written materials such as group discussions, GLOBE Science Notebooks, or weekly work reports.

Formal expressions of their knowledge through oral presentations and final reports need to be encouraged. These presentations and reports should inform listeners or readers comprehensively of the study in which the student participated. Students should be able to concisely express this information as scientists do at symposiums and in professional journals. Students also should be familiar, comfortable, and able to use the new scientific terminology they are learning. In this way, they will be better able to understand scientific literature and communicate precisely.

Learning to communicate in both formal and informal manners are not only essential science skills but will enable students to function better in adult life. They must be able to express themselves in a comprehensible manner to both their peers and the community.

To assess your students' learning over the course of this investigation, we recommend that you evaluate students based on their GLOBE Science Notebooks, presentations and reports, organization, understanding of concepts, measurement skill, data analysis and presentation, and soundness of conclusions.



Part One: How to Perform Your Soil Characterization

Students will locate a soil characterization sample site and prepare materials for field work.

Soil Characterization Field Measurements Protocol

Students will dig a hole, describe the characteristics of the horizons in the soil profile, and take samples of each horizon for analysis in the lab.

Soil Characterization Lab Analysis Protocol

Students will prepare samples for lab analysis and perform bulk density, particle size distribution, pH, and soil fertility measurements.

Part Two: Soil Moisture and Temperature

Students will locate a soil moisture study site and choose a sampling strategy and measurement frequency.

Gravimetric Soil Moisture Protocol

Students will measure soil water content 12 times per year using one of three sampling strategies.

Optional Gypsum Block Soil Moisture Protocol

Students will install gypsum blocks at four depths, measure their conductivity daily, and develop a calibration curve to permit conversion of the conductivity values to soil water content.

Infiltration Protocol

Students will measure the rate at which water soaks into the ground as a function of time.

Soil Temperature Protocol

Students will measure near-surface soil temperature weekly near local solar noon and seasonally throughout the diurnal year.

Part One: How to Perform Your Soil Characterization

Sample Sites for the Investigation

Each GLOBE school is expected to perform the Soil Characterization protocols for at least two study sites. These are the Soil Moisture Study Site (see *Part Two: Soil Moisture and Temperature*), and the Biology Study Site (see the *Land Cover/Biology Investigation)*. At each location, students dig a hole and examine the soil. Obtaining a soil profile to a depth of at least one meter into the ground is preferred wherever possible. Since the Soil Characterization Protocols are done only once for each location, the sites for which they are performed are referred to in GLOBE as Soil Characterization Sample Sites.

In many places, the soil profiles will vary significantly across the 15 km x 15 km GLOBE Study Site. Characterizing soil profiles at locations other than the two required sites can provide important additional science data and educational opportunities, and you are invited to do them. There is no limit on the number of soil characterizations you may submit to the GLOBE Student Data Server.

Some special opportunities may exist within your GLOBE Study Site to view soil profiles without digging. Road cuts may expose soil profiles; these can be sampled and characterized, but you should obtain a fresh profile face by removing the weathered surface with a shovel before proceeding with your observations and samples. Excavation sites are often interesting and usable. As always, make sure to be safe, and obtain any permissions required.

Locating a Soil Characterization Sample Site

There are several options for exposing and sampling the soil at a Soil Characterization Sample Site:

- Dig a soil pit at least 1 meter deep and as big around as is necessary to easily observe all of the soil horizons from the bottom to the top of the pit,
- Use a road cut, excavation site, or other location where others have exposed at least the top 1 meter of soil,
- Use an auger to remove soil samples to a depth of 1 meter, or
- Use a garden trowel or shovel to sample only the top 10 cm of soil if digging to a depth of 1 meter is not possible.

Some parts of the Soil Characterization Field Measurement Protocol are different depending upon which of these methods you are using.

If you will be digging to expose a soil profile, the Soil Characterization Sample Site should be:

- Safe for digging. Check with local utility companies and maintenance staff to ensure that you do not dig into or disturb a utility cable, water, sewer, or natural gas pipe, or sprinkler irrigation system of some kind,
- Under natural or representative cover. Find a relatively flat location with natural vegetation,
- Relatively undisturbed. Keep at least 3 meters from buildings, roads, paths, playing fields, or other sites where soils may have been compacted or disturbed by construction, and
- Oriented so that the sun will shine on the soil profile to ensure that the soil characteristics are clear for both naked-eye observations and photography.

Preparing for the Field

Bulk Density Containers

If your students have access to a soil drying oven, then they will be able to measure the bulk density of the soil layers. If not, skip this section and continue with the other materials to prepare.

If you are digging a soil pit, doing a near surface measurement or using a soil face exposed by others (road cut, excavation, etc.):

- Obtain 15 soil cans (enough for 5 horizons) or 3 cans if you will only be doing a near surface measurement.
- Label each can.
- Determine the volume of each can by:
  - Filling each can to the top with water (as full as you can).
  - Pouring the water into a graduated cylinder and measure its volume in mL (equal to cubic centimeters).
  - Recording the result on the Bulk Density Data Work Sheet. The volume of water that fills the can is equivalent to the volume of the can.
- Once the volume has been measured, make sure the can is dry and poke a small hole in the bottom of the can with a nail, to allow air in the can to escape when soil is being pressed into the can.
- Weigh each can.
- Record each weight on the Soil Bulk Density Data Work Sheet.
- Provide a lid or other means to seal each can for transport of the samples from the field to the laboratory.

If you are using the auger technique:

- Obtain 15 soil containers (enough for 5 horizons). In choosing containers remember the following:
  - The opening of each container should be large enough so that you can easily transfer a soil sample from the auger to the container without losing any of it.
  - The soil sample will be dried using a soil drying oven, and the best approach is to place the soil directly into the container in which it will be dried.
  - Plastic bags have big openings, but they melt and the soil sample must be transferred to metal, glass, or other containers before drying in the oven. Transferring the soil sample provides an opportunity for some of the sample to be lost.
  - The combined weight of your container and soil sample must not exceed the capacity of your scale or balance.
- Label each container.
- Weigh each container in which the soil will be dried.
- Record each weight on the Soil Bulk Density Data Work Sheet.
- Provide a lid or other means to seal each container for transport of the samples from the field to the laboratory.

Other Materials to Prepare

Fill a small acid bottle with distilled white vinegar to test for free carbonates.

Fill squirt bottles with water (it need not be distilled).

Make a clinometer if you do not already have one. See the *Land Cover/Biology Investigation.*

Soil Characterization Field Measurements Protocol

Purpose

To characterize the soils at the selected sites

To obtain additional site information

To gather samples from each horizon in order to perform later soil tests in the classroom

Overview

This protocol is divided into five tasks. In the first task, students will expose a 1 meter deep soil profile and identify the soil horizons. When this is not possible, a sample 10 cm deep can be taken to use for characterization. In the second task, students characterize the horizons by observing seven properties of soil layers. The students then perform the *Infiltration Protocol*, obtain additional site information, and take soil samples to use in determining bulk density, soil particle size distribution, soil pH, and soil fertility. In the final task, soil samples will be taken to the classroom and the drying of the samples begun.

Time

Preparation of materials - up to one class period

Soil pit including digging – up to one school day

Identifying horizons and taking samples from a soil pit - one or two class periods

Exposing and characterizing the soil profile using an auger and sampling – one or two class periods

Characterizing and taking a soil sample from 10 cm depth – one class period

Level

All

Frequency

Once at each of at least two sites (Soil Moisture Study Site and Biology Study Site).

Three samples of each horizon must be taken in the field for the *Soil Characterization Lab Analysis Protocol.*

Key Concepts

Soil horizon
Soil profile
Color
Texture
Structure
Consistence
Free carbonates
Bulk density
Root distribution
Soil measurements may be influenced by external factors such as land use, vegetation type, climate, parent material, and topography.
Sampling procedures

Skills

Describing soil characteristics
Using a clinometer
Describing a landscape
Collecting samples
Preparing samples for lab analysis

Materials and Tools

Garden trowels
Shovels
Dutch or other auger (See *Toolkit* for specifications)
Water bottle with squirt top (e.g. a well-rinsed dish-washing liquid bottle) or atomizer with a trigger for wetting soil)
Plastic sheet, tarp, board, or other surface on which to lay out a soil profile removed using the auger
Soil color book
Nalgene acid bottle filled with distilled white vinegar

Bulk density sample containers (or other sample containers if your school is not equipped to do bulk density measurements)
Block of wood
Hammer
Meter Stick or tape measure or chop sticks with metric units
20 nails, golf tees, or chop sticks for marking lower and upper boundaries of horizons
Soil Characterization Data Work Sheet
Bulk Density Data Work Sheet
Soil Characterization Information Sheet
Pencils
Water Proof Marker
Clip boards
Small towel for cleaning hands
Plastic bags or sealable containers roughly one-liter in size for transporting soil samples
One roll of tape for sealing the sample bags, cans, or other containers
A box, sack, or bucket for transporting soil samples to the classroom
One waterproof marker for labeling the sample bags
Clinometer for measuring slope (see *Land Cover/Biology Investigation*)
A camera and color film or a digital camera for photographing the soil profile and landscape (slides are acceptable)
GLOBE Science Notebooks

Preparation

Select the site, obtain permission to dig, prepare the bulk density containers, gather the other tools and materials, have the pit dug.

Prerequisites

Preliminary discussion of soil horizons, structure, color, consistence, texture, free carbonates, and bulk density

Preparation

Secure the Soil Characterization Data Work Sheet (one copy is enough for six horizons) on a clipboard.

Take along the Soil Characterization Information Sheet from the *Appendix* to help you take the field measurements, the MUC system pages including definitions (from the *Land Cover/Biology Investigation*), and your GLOBE Science Notebooks.

Assemble all the field measurement equipment:

- Digging equipment as appropriate: auger(s), shovel(s), garden trowel(s)
- Meter stick or tape measure with metric units
- Nails, chopsticks, golf tees, etc.
- Soil color book
- Squirt bottle(s) with water
- Acid bottle filled with distilled white vinegar
- Bulk density sample containers (or other sample containers if your school is not equipped to do bulk density measurements)
- Plastic bags or sealable containers roughly one liter in size for transporting soil samples
- Clinometer
- One roll of tape for sealing the sample bags, cans, or other containers
- A box, sack, or bucket for transporting soil samples to the classroom
- Hand towel(s)
- Pencils
- Waterproof marker(s)
- Camera
- GPS if available

In addition for the auger technique:

- Plastic bag, tarp, board, or other surface on which to lay out the soil profile
- Copies of the Bulk Density Data Work Sheet for the Auger Technique (one copy is needed for each horizon so have at least five copies available)

How to Expose and Identify Soil Horizons

Soil Pit Technique

With this technique, students (or others) expose the soil profile by digging a soil pit.

1. Dig a pit one meter deep and as big around as is necessary to easily observe all of the soil horizons from the bottom to the top of the pit. As soil is removed from the pit, place the soil from each horizon in a separate pile. After the observations have been made and samples taken, the soil should be returned in the opposite order in which it was removed (i.e. the soil taken from the bottom of the pit should go in first, etc.).
2. If you need help to dig the soil pit, call upon parents, other teachers, custodians, student athletes, and local agricultural service personnel.
3. Have students look at the side of the soil pit on which the sun shines most directly so that soil properties will be clearly visible.
4. Starting from the top of the profile and moving down to the bottom, observe the soil profile closely to identify where there are changes in the appearance of the soil face.
5. Look carefully for any distinguishing characteristics like different colors, roots, the size and amount of stones, small light or dark nodules (called *concretions*), worms or other small animals and insects, worm channels, and anything else that is noticeable. If the soil is very dry, wetting it with your squirt bottle may help to distinguish color difference between horizons.
6. Mark the location of each of these changes or boundaries by sticking a nail, golf tee, chop stick, or other marker into the soil face. Sometimes it is difficult to identify differences in horizons because the properties of the whole soil profile are very similar. In this case, there may be only a few very thick horizons present. Do your best to record exactly what you observe in the field.
7. Measure the top and bottom depths for each horizon to the nearest cm and record them on Soil Characterization Data Work Sheet.
8. If horizons are very thin, (<3 cm from top to bottom) do not describe them as separate horizons; combine them with the horizon above or below instead. Thin horizons should be noted in your GLOBE Science Notebooks. Students who wish to do so can identify the horizons by letter name using the descriptions given in the Introduction Section.
9. Proceed to characterize the properties of each of the soil horizons identified. Perform this characterization as soon as possible after the pit is dug.
10. Once this protocol is completed, students should fill in the pit with the original soil. If there are educational or other reasons why the pit is not refilled immediately, take appropriate precautions to ensure that the pit is not a hazard.

Existing Exposed Soil Profiles (a road cut, excavation, etc.)

1. Obtain permission to take samples from the road cut, excavation, or other soil profile exposed by others. Obey any and all safety precautions requested.
2. Expose a fresh soil face by scraping the soil profile with the edge of the garden trowel or other digging tool to remove the surface layer.
3. Perform Steps 4 - 10 as given for the Soil Pit Technique.

Auger Technique

With this technique, students display the vertical soil profile on a horizontal surface (the ground). Be sure to use the correct auger for your site. A Dutch auger, as described in the *Toolkit* is best for most soil, especially for rocky, clayey, and dense soils. A sand auger is needed if your soil is very sandy in texture. In some places, the soil is mostly peat and a special peat auger should be used. A bucket auger may be better for dry, desert soils.

1. Identify an area where you can dig four auger holes where the soil profiles should be similar.
2. Spread a plastic sheet, tarp, board, or other surface on the ground next to where you will dig your first hole.
3. Assemble a profile of the top 1 meter of the soil by removing successive samples from the ground with the auger and laying them end-to-end as follows:

   3.1. Turn the auger one complete revolution (360°) to dig into the ground.

   3.2. Remove the auger with the sample in it from the hole.

   3.3. Hold the auger over the plastic sheet, tarp, or board.

   3.4. Transfer the sample from the auger to the plastic sheet, tarp, or board as gently as possible. Place the top of this sample just below the bottom of the previous sample.

   3.5. Measure the depth of the hole. Adjust the sample on the plastic bag, tarp, or board so that its bottom is no further from the top of the soil profile than this depth.
4. Starting from the top and moving down to the bottom, observe the soil profile closely to identify where there are changes in the appearance of the soil.
5. Look carefully for any distinguishing characteristics like different colors, roots, the size and number of stones, small light or dark nodules (called *concretions*), worms or other small animals and insects, worm channels, and anything else that is noticeable.
6. Mark the location of each of these changes or boundaries by sticking a nail, golf tee, chop stick, or other marker into the soil profile you have constructed. Sometimes it is difficult to identify differences in horizons because the properties of the whole soil profile are very similar. In this case, there may be only a few very thick horizons present. Do your best to record exactly what you observe in the field.
7. Measure the top and bottom depths for each horizon to the nearest cm and record them on Soil Characterization Data Work Sheet(s).
8. If horizons are very thin, (<3 cm from top to bottom) do not describe them as separate horizons, but combine them with the horizon above or below instead. Thin horizons should be noted in your GLOBE Student Data Notebook. Students who wish to do so can identify the horizons by letter name using the descriptions given in the *Introduction* section.
9. Proceed to characterize the properties of each of the soil horizons identified. Perform this characterization as soon as possible after the hole is augered.
10. Once these tasks are completed, where ever possible, students should fill in the hole with the original soil.

Near Surface Sample Technique

1. In situations where it is not possible for you to expose the top meter of soil, an additional option is to use the top 10 cm of the soil as a single horizon sample for soil characterization.
2. Use a garden trowel or shovel to carefully remove the top 10 cm of the soil from a small area and set it on the ground.
3. Treat this sample as a horizon and proceed to characterize its properties.

How to Observe and Record Soil Properties

For each horizon identified, the following characteristics should be observed, recorded on the Soil Characterization Data Work Sheet, and reported to the GLOBE Student Data Server using the Soil Characterization Data Entry Sheet. **Note:** The soil characteristics should be observed in the order given.

1. Soil Structure

Take a sample of undisturbed soil in your hand (either from the pit or from the shovel or auger). Look closely at the soil in your hand and examine its structure. Soil structure is the shape that the soil takes based on its physical and chemical properties. Each individual unit of natural soil structure or aggregation is called a *ped*. Possible choices of soil structure are granular, blocky, platy, columnar, and prismatic, and are shown in Figures SOIL-P-1 to 5.

Sometimes your soil may be structureless, which means that within a horizon, soil peds have no specific shape. In this case, the soil structure is either single grained or massive. Single grained is like sand at a beach or in a playground where there are individual sand particles that do not stick together. Massive is when the soil sticks together in a large mass that does not break in any pattern. These conditions are more commonly found in C horizons, the horizons in which the parent material is least altered. Since the parent material has not yet undergone any weathering, it usually has not developed any structure.

It is common to see more than one type of structure in a soil sample. Students should record on their data sheets only the structure type that is most common in their sample. They should discuss and agree upon the structure types they see. If the sample is structureless, record whether it is single-grained or massive.

2. Soil Color

Take a ped from the horizon and note on the data sheet whether it is moist, dry, or wet. If it is dry, moisten it slightly with water from your water bottle. Break the ped and hold the color chart

Figure SOIL-P-1: Blocky Structure

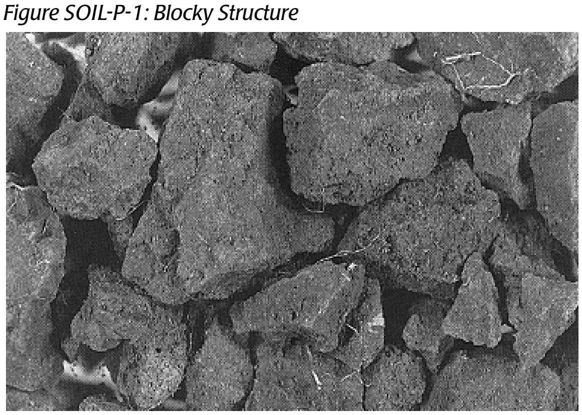


Figure SOIL-P-2: Columnar Structure

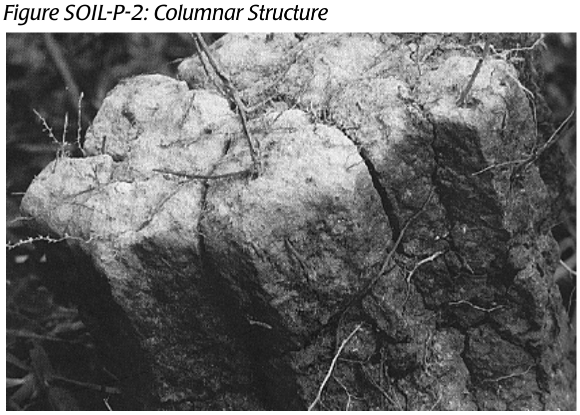


Figure SOIL-P-3: Granular Structure

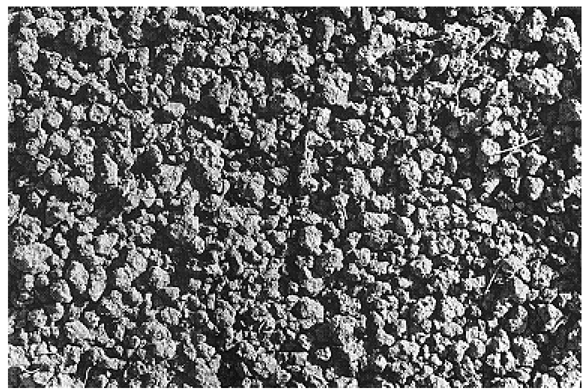


Figure SOIL-P-4: Platy Structure

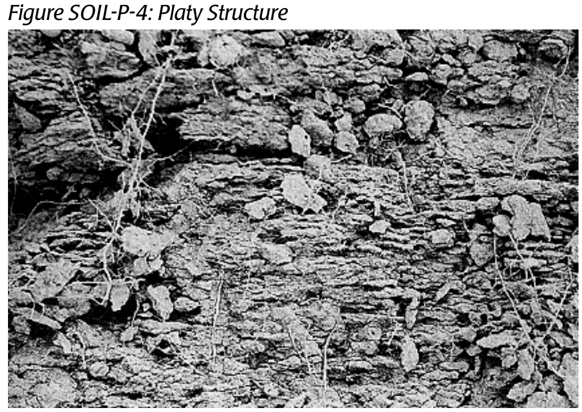
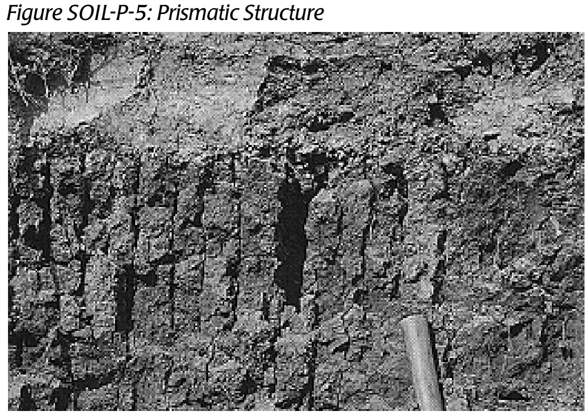


Figure SOIL-P-5: Prismatic Structure



next to it. Find the color from the color chart which most closely matches the color of the inside surface of the ped. Stand with the sun over your shoulder so that sunlight shines on the color chart and the soil sample you are examining. Record on the data work sheet the symbol of the color on the chart that most closely matches the soil's color.

Sometimes, a soil sample may have more than one color. Record a maximum of two colors if necessary, and indicate (1) the dominant (main) color, and (2) the sub-dominant (other) color. Again, students both inside and outside the pit should agree on the choice of color.

3. Soil Consistence

Take a ped from the soil horizon. Record on the data work sheet whether the ped is moist, wet or dry. If the soil is very dry, moisten the face of the profile by squirting water on it, and then remove a ped for determining consistence. Holding the ped between your thumb and forefinger, gently squeeze it until it pops or falls apart. Record one of the following categories of soil ped consistence on the data sheet.

Loose: You have trouble picking out a single ped and the structure falls apart before you handle it.
Friable: The ped breaks with a small amount of pressure.
Firm: The ped breaks when you apply a good amount of pressure and the ped dents your fingers before it breaks.
Extremely Firm: The ped can't be crushed with your fingers (you need a hammer!)

4. Soil Texture

The texture of a soil refers to the amount of sand, silt, and clay in a soil sample, and the composition of these determines the way the soil feels when you rub it between your fingers. The texture differs depending on the amount of sand, silt, and clay in the soil sample. Sand particles are the largest with sizes up to 2 mm while clay particles are smaller than .002 mm. Particles greater than 2 mm are called stones or gravels and are not considered to be soil material. Even though they are small, the differences among sand, silt, and clay particles can be felt, and each has its own characteristics. Sand feels gritty, silt feels smooth, and clay feels sticky. Usually a combination of these different size particles is found in a soil sample. Soil scientists use charts called textural triangles to help determine what percent of sand, silt, and clay are in a soil. Using Textural Triangles 1 and 2 to help you, follow these steps to identify your soil's texture.

4.1. Take a sample of soil about the size of a small egg and add enough water to moisten it. Work it between your fingers until it is the same moisture throughout. Then, squeeze it between your thumb and forefinger in a snapping motion to try to form a ribbon of soil.

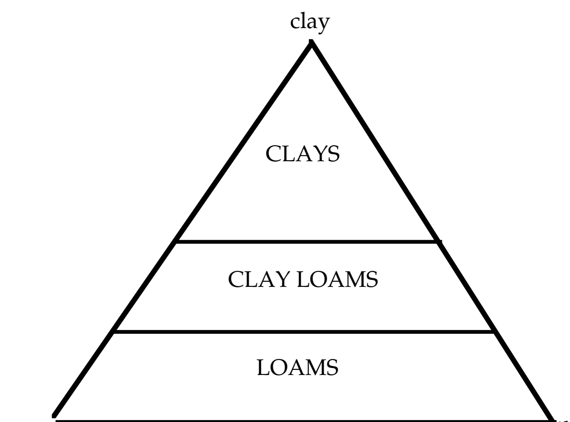


Figure SOIL-P-6: Textural Triangle 1

4.2. If the soil feels extremely sticky (sticks to your hands and is hard to work), stiff and requires a lot of thumb and finger pressure to form a ribbon, it is likely composed of mostly clay size particles. Classify it as a clay, as shown on Textural Triangle 1.
4.3 If the soil feels sticky and a little softer to squeeze, it probably has fewer clay particles. Classify it as a clay loam.
4.4 If the soil is soft, smooth, and easy to squeeze, and is at most slightly sticky, classify it as a loam.

Once the soil has been classified as clay, clay loam, or loam, refine the classification by determining the relative amounts of sand and silt.

4.5 If the soil feels very smooth, with no sandy grittiness, add the word "silt" or

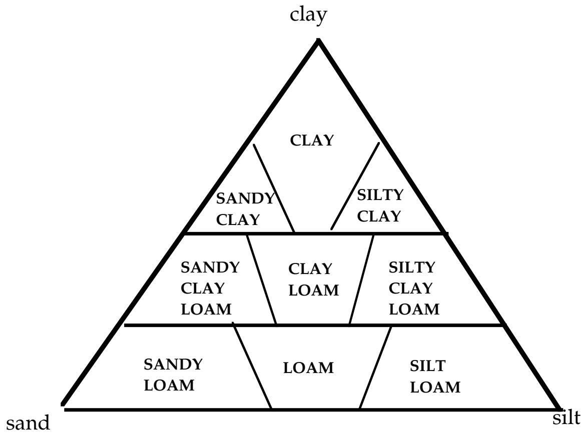


Figure SOIL-P-7: Textural Triangle 2

"silty" to your classification, such as "silty clay", or "silty loam", as shown on Textural Triangle 2. This means that your soil sample has more silt-size particles than sand-size particles.

4.6 If the soil feels very gritty, add the term "sandy" to your soil classification, such as "sandy clay". This means your soil sample has more sand size particles than silt size particles.

4.7 If the soil feels neither very gritty nor very smooth, even if you can feel some sand in your sample, keep your original classification unchanged. This means your soil sample has about the same amounts of sand and silt size particles, and in the case of a clay, it may have very few of either.

Note: When feeling the soil texture, try to add the same amount of water to each sample so that you can more accurately compare one texture to the other. The soil texture can feel differently depending on how wet or dry it is. The amount of organic matter in the soil can also change how it feels. Generally, the darker the soil color is, the more organic matter is in it.

4.8 Record on the data work sheet the name of the soil texture that the students agree on. Also, note whether the sample was dry, wet, or moist when it was examined, and whether it contained a lot of organic matter (for instance if it was on the surface and had a very dark color).

5. Presence of Roots

Observe and record if there are none, few, or many roots in the horizon.

6. Presence of Rocks

Observe and record if there are none, few, or many rocks or rock fragments in the horizon. A rock or rock fragment is defined as being larger than 2 mm in size.

7. Test for Free Carbonates

Perform this test by squirting vinegar on the soil. If carbonates are present, there will be a chemical reaction between the vinegar, and the carbonates to produce carbon dioxide. When carbon dioxide is produced, it bubbles or *effervesces*. The more carbonates that are present, the more bubbles (*effervescence*) you will observe.

7.1. Look carefully at your soil profile for white coatings on the soil and rocks which might indicate that free carbonates are present.

7.2. Set aside a portion of the pit, exposed soil face, or sample from the auger hole or near surface which you do not touch with your hands, and use it for the free carbonates test.

7.3. After you have finished characterizing the other soil properties, test for free carbonates. Open the acid bottle and starting from the bottom of the profile and moving up, squirt vinegar on the soil particles. Look carefully for the presence of effervescence.

7.4 Record one of the following as the results of the Free Carbonate Test for each horizon:

<u>None:</u> if you observe no reaction, the soil has no free carbonates present.

<u>Slight:</u> if you observe a very slight bubbling action; this indicates the presence of some carbonates.

<u>Strong:</u> if there is a strong reaction (many, large bubbles) this indicates that many carbonates are present.

7.5. Do not bring samples contaminated with the vinegar back to the classroom.

Obtain Additional Site Information

At the same time that students take their soil characterization measurements in the field, or within a few months thereafter, spend some time with your class describing and recording details about your site.

1. Measure and record the GPS coordinates of your site.
2. Perform the *Infiltration Protocol* for three places near your soil pit, auger hole, or surface sample, or above the road cut or other excavation. You do not need to measure infiltration on more than one day; the day you are collecting the other soil characterization data is usually a good day to take this measurement.
3. Photograph the soil profile that has been described. Do this on the day measurements are taken in the field.

   If students have exposed the soil profile by digging a soil pit or have used an existing exposed soil profile, place a tape measure or meter stick along the profile with the 0 cm mark at the ground surface. Photograph the profile face from outside the pit, preferably with the sun behind the photographer shining on the exposed profile.

   If the soil profile was obtained with an auger, photograph the soil profile lying on the paper or board on the ground with a tape measure or meter stick lying next to it. Again, have the 0 cm mark at the top or ground surface level of the profile, and have the sun behind the photographer.

   In either case, take another photograph of the landscape around the Soil Characterization Sample Site.

   Send copies of these photographs to the GLOBE Student Data Archive at the address given in the Implementation Guide, or if they were taken with a digital camera, submit them to the GLOBE Student Data Archive electronically.
4. Measure the slope of the sample site using the clinometer from the *Land Cover/Biology Investigation*, and record the slope measurement on the Soil Characterization Data Work Sheet.

   4.1 Designate two students whose eyes are at about the same height to measure the slope.

   4.2 Measure the steepest slope that crosses the hole.

   4.3 The student that holds the clinometer stands down slope and the other walks to the opposite side of the hole.

   4.4 Looking through the clinometer, one student sites the eye level of the other student.

   4.5 Read the angle of slope in degrees and record this reading on the data work sheet.
5. Measure and record the distance from major features (such as buildings, power poles, roads, etc.).
6. Record any other distinguishing characteristics that make this site unique. (While all of the following data will not be reported to GLOBE at the current time, such data should be recorded in the school's local database.)

   Questions you might ask are:

- What are the types of plants and animals you find in the soil and the general area around your site? Include small organisms in the soil such as earthworms or ants.
- What is the parent material from which the soil was formed? Was it bedrock? If so, look for rocks on the surface to tell you something about the kind of rock. Could your soil have been deposited by water or wind, by a glacier or volcano? If necessary, further investigate the surface geology of your area in your local library.
- Where in the landscape is your soil? Is it on a hilltop, slope, or bottom of a hill? Is it next to a stream or on a flat plain? On what kind of land form is it found?
- What is the general climate at your soil site? Is it sunny, shaded, hot, cold, moist, dry?
- What is the recent land use in this area? Has it been stable for a long time, or has it been plowed, its trees cut, used for

construction, or undergone some other disturbance recently?

7. Record all requested information on the Soil Characterization Data Work Sheet.

Information about your site and data collection techniques (often called metadata) should be entered permanently in your GLOBE Science Notebook and registered with your site using the Soil Characterization Sample Site Data Entry Sheet. You are not required to enter all this information, but it is of great help to scientists and others who want to use these data. A sample site must be defined before the soil characterization data for it can be entered. Initially, this definition can consist of no more than a name for the site and the date on which the field observations were made and the soil samples taken. As more information becomes available to characterize the sample site, these data can be added to the GLOBE Student Data Archive using the modify a sample site procedure.

Soil Sampling

The methods for obtaining soil samples for further analysis are different depending on how you have exposed your soil profile.

Soil Pit Technique and Existing Exposed Soil Profiles

Taking Bulk Density Samples

1. For each horizon in your soil profile, push a can with a known volume into the side of the horizon. The soil in the profile should be moist, so that it will stick together and so that the can will go in easily. If necessary, wet the soil before doing this measurement.
2. If it is still difficult to push the can into the soil, you may need to use a hammer or other object to force it in. If this is necessary, place a piece of wood over the can and hit the wood with the hammer to spread the force of the hammer blow to all edges of the can at once and to minimize denting the can.

   Note: Some denting is allowed in this procedure as long as the volume of the can is not changed by more than a few percent, but if the can dents too badly, the soil may be too hard or rocky to take a bulk density sample this way. You might consider taking a bulk density sample using the auger method described below, instead, for the dense horizons.
3. Stop when you can see some of the soil poking through the small hole in the bottom of the can, the can has been filled with soil.
4. Using a trowel or shovel, remove the can and the soil surrounding it. Trim the soil from around the can until it is flat against the edges of the can so that the volume of the soil is the same as the volume of the can.
5. Cover the can with the lid or other cover and return it to the classroom.
6. Repeat this procedure so that you have 3 bulk density samples for each horizon.
7. Label the cans in the field with the site name, horizon number (or letter), top and bottom depths, and sample number (1, 2 or 3 for each horizon).
8. Bring these samples in from the field as soon as possible.
9. Remove the covers.
10. Weigh each sample in its can and record this moist weight on the Bulk Density Data Work Sheet.
11. Place the samples in the soil drying oven.

If you are not measuring bulk density:

1. Dig an ample sample from each soil horizon. Avoid the area of the soil face which was tested for carbonates and avoid touching the soil samples so that your pH measurements will not be contaminated.
2. Place each sample in a bag or other soil container.
3. Label each bag with the site name, horizon number (or letter), and top and bottom depths.
4. Bring these samples in from the field.
5. Spread the samples on separate plastic plates or sheets of newspaper to dry in the air.

Auger Technique

Three samples are needed from each horizon. Each will be obtained from a new auger hole.

Taking Bulk Density Samples:

For each auger hole:

1. Auger to a depth 1 or 2 cm past the top of the horizon to be sampled.
2. Measure the depth of the hole.
3. Use the auger to remove a sample of the horizon. If the horizon has a smaller vertical extent than the length of the auger head, only perform a partial turn of the auger so that the whole sample will be from just this horizon. Do not turn the auger more than one complete circle (360°) so that the soil does not become compacted.
4. Once the sample is removed, transfer all the soil from the auger head to a sample container without losing any on the ground. Avoid handling the sample as much as possible to minimize the soil contamination by natural oils from your skin.
5. Measure the diameter of the hole that the auger made, and the depth of the hole.
6. Label the outside of the container with the horizon name, the diameter of the hole, and depth of the hole before and after this sample was removed. (These measurements will be used to calculate the volume of the sample.)
7. Repeat steps 1 - 6 for each horizon in the soil profile.
8. Repeat this procedure in different holes, next to each other, so that you obtain 3 samples of each horizon.
9. Cover or seal the samples and transport them to the classroom.
10. Bring these samples in from the field as soon as possible.
11. Remove the covers.
12. Weight each sample in its container and record this moist weight on the Bulk Density Data Work Sheet.
13. Place the samples in the soil drying oven.

If you are not measuring bulk density:

For each auger hole:

1. Auger to a depth 1 or 2 cm past the top of the horizon to be sampled.
2. Use the auger to remove a sample of the horizon. If the horizon has a smaller vertical extent than the length of the auger head, only perform a partial turn of the auger so that the whole sample will be from just this horizon.
3. Place the sample in a bag or other soil container. Avoid contaminating the sample by touching it with your hands.
4. Label each bag with the site name, horizon name, and top and bottom depths of the horizon.
5. Repeat Steps 1 - 4 for each horizon.
6. Bring these samples in from the field. Spread the samples on separate plastic plates or sheets of newspaper to dry in the air.

Near Surface Sample Technique

Taking Bulk Density Samples:

1. Choose 3 locations close to the location where you performed your *Soil Characterization Protocol*.
2. Remove vegetation and other material from the soil surface.
3. For each of the 3 locations:

   3.1. Push a can with a known volume into the surface of the soil. The soil in the profile should be moist, so the soil will stick together, and the can will press into the ground easily. If necessary, wet the soil before doing this measurement. Let the moisture seep into the soil before sampling. It is preferable to sample moist soils and not wet soils unless the soil is naturally saturated with water.

   3.2. Stop when you can see some soil poking through the small hole in the bottom of the can, you have filled the can.

   3.3. If it is difficult to push the can into the soil, you may need to use a hammer or other object to force it in. If this is necessary, place a piece of wood over the can and hit the wood with the hammer to spread the force of the hammer blow to all edges of the can at once and to avoid denting the can.

3.4. Slide a trowel or shovel under the can and the soil surrounding it and lift it out carefully. Trim the soil from around the can until it is flat against the edges of the can so that the volume of the soil is the same as the volume of the can.

3.5. Cover the can with the lid or seal it for transport back to the classroom.

3.6. Label the cans in the field with the site location and the number of the sample (i.e. 1, 2 or 3).

4. Bring these samples in from the field as soon as possible.
5. Remove the covers.
6. Weigh each sample in its can and record this moist weight on the Bulk Density Data Work Sheet.
7. Place the samples in the soil drying oven.

If you are not measuring bulk density:

1. Dig an ample sample from the top 10 cm of the soil. Avoid the area which was tested for carbonates, and avoid touching the soil samples so that your pH measurements will not be contaminated.
2. Place each sample in a bag or other soil container.
3. Label each bag with the site name, horizon name, and top and bottom depths.
4. Bring these samples in from the field.
5. Spread the samples on separate plastic plates or sheets of newspaper to dry in the air.

Soil Characterization Lab Analysis Protocol

Purpose

To determine the bulk density of the soil

To determine the soil particle size distribution

To measure soil pH

To determine soil fertility by measuring the amounts of nitrate nitrogen, phosphorus, and potassium (N, P, K) in the soil

Overview

In the classroom/laboratory, students will dry the bulk density samples in an oven, weigh them, sieve them to remove rocks, and determine the weight and volume of the rocks. The sieved bulk density or other samples will be used to determine the particle size distribution, the soil pH, and the soil fertility (N, P, K).

Time

For drying soil samples, allow at least 10 hours for drying at 95 - 105 ^{o} C, 24 hours for drying at 75 - 95 ^{o} C, or two days for air drying (no classroom time is involved).

Preparation of dispersing solution needed prior to class - 10 minutes

Dispersing step for Particle Size Distribution procedure, sieving dry samples and completing the bulk density measurement - one class period

2 and 12 minute measurements for Particle Size Distribution, and measurements of Soil pH and Soil Fertility - one class period

Final Particle Size Distribution measurement, clean up, and review of all the data - one class period

Level

Soil Fertility (N, P, K) — Intermediate and Advanced.

Other measurements — All

Frequency

Once for each horizon

Three samples for each horizon

Key Concepts

Volume
Density
Bulk density
pH of soil
Soil fertility (N, P, K)
Soil nutrients
Chemical reactions
Specific gravity
Particle size distribution
Texture
Supernatant

Skills

Handling samples
Sieving samples
Recording data
Manipulating scientific equipment
Observing color
Pipetting
Measuring pH, specific gravity, and soil fertility
Determining relative nutrient content
Using a hydrometer

Materials and Tools

<u>For Recording Data During All Measurements:</u>

Bulk Density Data Work Sheet
Particle Size Distribution Data Work Sheet
pH Data Work Sheet
Soil Fertility Data Work Sheet

<u>For Drying and Sieving Samples:</u>

Newspapers or plastic plates
#10 sieve (2 mm mesh openings)

Liter-size bags, jars, or containers for storing soil samples
Balance
Rubber gloves

For Bulk Density
Drying oven or microwave
100 mL graduated cylinder to determine volume of rocks
Balance

For Particle Size Distribution:
Rolling Pin, hammer, or other utensil for crushing peds and separating particles
500 mL clear plastic graduated cylinder
Hydrometer
Thermometer (needs to have a smooth surface without a cover so that soil and water do not got trapped)
Spoon or other utensil to transfer soil
Spoon or stirring rod for stirring soil
Dispersing solution (50 g Sodium Hexametaphosphate/liter or non-sudsing powdered detergent containing sodium and phosphate)
250 mL or larger beaker
Squirt bottle for washing soil out of beaker
Stop watch or a clock with a second hand
Plastic Wrap or other material to cover top of cylinder during shaking
1 L bottle for dispersing solution

For pH:
Three 100 mL-beakers
Balance
pH paper, pen, or meter
Glass stirrer or spoon
Distilled water
100 mL-graduated cylinder to measure distilled water

For Soil Fertility:
Distilled water
Soil Fertility Kit with reagents to measure N, P, and K
Teaspoon
Cup or test tube rack to hold tubes

For Disposing of Soil:
Buckets or other large water tight containers

Preparation

Calibration of pH meter or pen

Prerequisites

Soil Characterization Field Measurement

How to Measure Bulk Density and Prepare Samples for Other Lab Analyses

Bulk Density

1. Dry the samples in their containers following the directions given for drying samples in the *Gravimetric Soil Moisture Protocol*.
2. Weigh each dry bulk density sample in its container and record this dry weight on the Bulk Density Data Work Sheet.
3. Rocks don't hold water or store nutrients, so they don't contribute to the bulk density of soil.

To determine the density of any rocks that are in a sample use the following procedure (if there are no rocks in your sample, skip this part):
3.1 Place a large piece of paper (such as newspaper) on a table and put the #10 (2 mm openings) sieve on top of it. Pour one sample into the sieve.
3.2 Put on rubber gloves to avoid contaminating your sample with acids from your skin.
3.3 Carefully push the dried soil material through the mesh onto the paper. Do not force the soil through the sieve as this may bend the mesh openings. Rocks will

not pass through the mesh and will stay on top of the sieve. If no sieve is available, carefully remove the rocks by hand.

3.4 Save the sieved soil from each sample for the other lab analyses.

3.5 Weigh the rocks, and record this weight on the Bulk Density Data Work Sheet.

3.6 Place 30 mL of water in a 100 mL graduated cylinder, and without spilling, add the rocks to the water. Read the level of the water after all the rocks have been added and record this value and the original volume of water on the Bulk Density Data Work Sheet.

As you add the rocks, if the volume of the water comes close to 100 mL, record the increase in volume, empty the cylinder and repeat the procedure for the remaining rocks. In this case, you must calculate and record the sum of the water volumes with the rocks and the sum of the water volumes without the rocks.

Making Sense of the Data

When you are done, the following should have been recorded on your Bulk Density Data Work Sheet and reported to the GLOBE Student Data Server using the Bulk Density Data Entry Sheet:

- the volume of the soil can (mL) (For the pit or surface sampling method)
- the weight of the soil can (g) (For the pit or surface sampling method)
- the diameter of the hole (cm) (For the auger method)
- the top and bottom depth of the hole (cm) (for the auger method)
- the weight of the container (g) (for the auger method)
- the weight of the moist soil and container (g) (only needed if you wish to calculate soil water content)
- the weight of the dry soil and container (g)
- the weight of the rocks (g)
- the volume (or sum of the volumes) of the water added to the graduated cylinder before rocks are added (mL)
- the volume (or sum of the volumes) of the water after rocks have been added (mL)

To calculate soil water content:

In doing the bulk density measurements, if you measured the weight of the moist soil and container you have obtained all the information needed to determine the soil water content of your sample. If you wish to know the soil water content, follow the procedures for this calculation given in the *Gravimetric Soil Moisture Protocol*. These soil water content values are not reported to GLOBE; they are only for student practice and added insight.

If you are not measuring bulk density

Prepare the samples for the lab analyses.

1. Place a large piece of paper (such as newspaper) on a table.
2. Put the #10 (2 mm openings) sieve on top of it.

The bulk density of the soil material (in units of g/cm^3) can now be calculated for each sample by:

$$\text{Bulk density} = \frac{\text{dry weight} - \text{container weight} - \text{weight of rocks}}{\text{container or hole volume} - \text{volume of rocks}}$$

$$\text{Hole volume} = \pi \times \left[\frac{\text{hole diameter}}{2}\right]^2 \times [\text{bottom depth of hole} - \text{top depth of hole}]$$

Volume of rocks = volume of water and rocks – volume of water before rocks were added

If you had to measure the volume of rocks in more than one batch, add the volumes calculated for each batch to get the total volume of rocks.

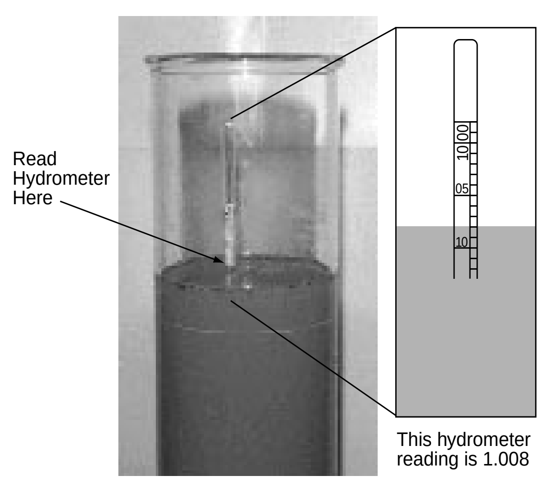
3. Pour the sample into the #10 sieve. Put on rubber gloves so the acids in your skin don't contaminate the soil pH measurement.
4. Carefully push the dried soil material through the mesh onto the paper. Do not force the soil through the sieve or you may bend the wire mesh openings. Rocks will not pass through the mesh and will stay on top of the sieve. Remove the rocks (and other pieces of debris) from the sieve and discard. If no sieve is available, carefully remove the rocks and debris by hand.
5. Transfer the rock-free, dry soil from the paper under the sieve into new, clean, dry plastic bags or containers.
6. Seal the containers, and label them the same way that they were labeled in the field (horizon name, top and bottom horizon depth, date, site name, site location). This is the soil that will be used for the other lab analyses.
7. Store these samples in a safe, dry place until they are used.

How to Measure Soil Particle Size Distribution

Repeat this measurement three times for each horizon, and record all sets of data on the Particle-Size Distribution Data Work Sheet.

1. Prepare the dispersing solution by mixing 50 g of Sodium Hexametaphosphate (or other material as indicated above), in 1 L of distilled water. Dissolve all of the solid material by stirring the mixture.
2. After drying and sieving the soil samples, use a rolling pin, mortar and pestle, or hammer to break up any large particles that might still be present.
3. Weigh 25 grams of dried, sieved soil and pour it into a 250 mL or larger beaker. Pour 100 mL of the dispersing solution and about 50 mL of distilled water into the beaker. Stir vigorously with a spoon or stirring rod for at least one minute. Be sure the soil is thoroughly mixed and does not stick to the bottom of the beaker. Do not spill any of the soil suspension.
4. When the soil and dispersing solution are thoroughly mixed, rinse any soil left on the stirrer into the beaker with the rest of the mixture. Set the beaker aside in a safe place and allow it to sit for about 24 hours (the sample can be left to mix with the dispersing solution over the weekend as well).
5. While the suspension is sitting, put a meter stick or other ruler in the cylinder and measure the distance between the 500 mL mark and the bottom of the cylinder. Also read the temperature at which your hydrometer has been calibrated (such as 15.6° C or 20° C). This number will be found somewhere on the hydrometer. Record both on the Particle Size Distribution Data Work Sheet.
6. After roughly 24 hours (or during the same class period the next school day), stir the suspension in the beaker again, and pour it into a 500 mL graduated cylinder.
7. Using a squirt bottle, rinse out the beaker with distilled water, and add this to the soil mixture in the cylinder.
8. Add enough distilled water to fill the cylinder to the 500 mL mark.
9. Securely cover the top of the cylinder using plastic wrap or another secure cover.

Figure SOIL-P-8



Note: The increased volume level (apparently greater than 500 ml) is caused by the displacement of water by the hydrometer.

10. Mix vigorously by rotating the covered cylinder hand-over-hand at least 10 times. Be sure the soil is thoroughly mixed in the solution and does not stick to the bottom of the cylinder. Also, try not to let any of the soil suspension leak out the top.
11. Gently set the cylinder down in a safe place, and immediately begin timing with a stop watch or clock with a second hand.
12. Record the time that the cylinder was set down to the second.
13. After $1^1/_2$ minutes, carefully lower (do not drop) the hydrometer into the cylinder and allow it to float in the soil suspension. Steady the hydrometer to suppress its bobbing up and down.
14. Exactly 2 minutes after the cylinder was set down, read the line on the hydrometer that is closest to the surface of the soil suspension. See Figure SOIL-P-8.

    Note: Read the hydrometer for the Soil Particle Size Distribution protocol the same way that is read for the *Salinity Protocol.*
15. Remove the hydrometer, rinse it, dry it, and gently put it down in a safe place.
16. Suspend the thermometer in the soil suspension in the cylinder for about 1 minute.
17. At the end of 1 minute, remove the thermometer from the suspension, read the temperature, and record the result on the Data Work Sheet.
18. Rinse the thermometer off and dry it.
19. Allow the cylinder to sit safely without being disturbed.
20. Take another hydrometer measurement in the undisturbed cylinder at 12 minutes. Place the hydrometer carefully in the suspension about 30 seconds before taking the reading to allow it to settle.
21. Take and record another temperature reading for the suspension.
22. Rinse the hydrometer and thermometer off when they have been removed from the suspension and dry them.
23. Record these results on the Particle Size Distribution Data Work Sheet.
24. Leave the cylinder undisturbed for 24 hours (or until the beginning of the same class period the next day). **Note:** this time period is critical and should not be significantly longer than 24 hours.
25. Take another hydrometer and temperature reading.
26. Record the results on the Data Work Sheet.
27. Discard the soil suspension by pouring it into a special pail, and spill the contents outside in a place for discarding soil materials. DO NOT pour the suspension down the sink!
28. Carefully rinse and dry the hydrometer, thermometer, beakers, and cylinders, and repeat the above steps 2 more times for the same horizon so that you have a total of 3 sets of results for this horizon.

Note: This measurement involves considerable waiting time and must be done for three samples from each horizon in the soil profile. The number of days required to complete the set of measurements depends on the amount of equipment available. After a sample is mixed with dispersing solution and water initially, it should stand for a day before proceeding to do the measurement, and after the first two measurements, the sample sits undisturbed for 24 hours more. If your soil profile has five horizons, this task must be done 15 times. If only one 500 mL cylinder is available, the measurement of all the samples must be spread out over many days. Having multiple 500 mL cylinders would allow you to accelerate this process. One hydrometer should be adequate for use with at least three cylinders if the starting times of the settling are staggered by about three minutes. However, a single 500 mL cylinder and hydrometer are adequate for use in the *Hydrology Investigation Salinity Protocol*, and if your students will be doing the soil characterization only a few times spread over several school years, then the same cylinder and hydrometer can be reused and the particle size distribution measurements spread over several weeks to save on equipment costs.

How to Measure pH

Make this measurement on three samples for each horizon.

Mix Soil and Distilled Water

1. In cup or beaker, mix dried and sieved soil with distilled water in a 1:1 soil to water ratio (e.g. mix 20 g of soil with 20 mL of water, mix 50 g of soil with 50 mL of water). Mix enough soil and water so that the pH reading can be made in the *supernatant* (the clearer liquid above the settled soil particles). Use a spoon or other utensil but not your hands to transfer the soil. Oils and other materials on your hands may contaminate the pH reading. Stir with a spoon or other stirrer until the soil and water are thoroughly mixed.
2. Stir the soil-water mixture every 3 minutes for 15 minutes. After 15 minutes, allow the mixture to settle until a supernatant forms (about 5 minutes).

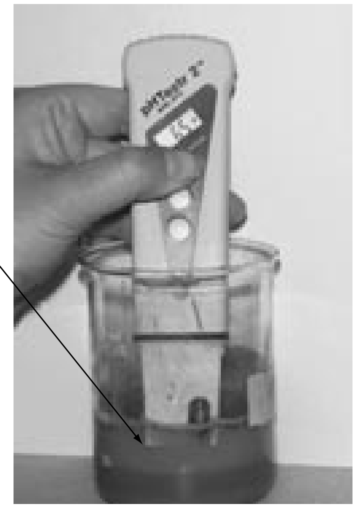
With pH paper (Beginning Level):

1. In a cup or beaker, measure the pH of the water you are using for this protocol by dipping the pH paper into the water and comparing the color to the color chart (as described in the *Hydrology Investigation pH Protocol*).
2. Measure the pH of the supernatant by dipping the pH paper into it (following the procedure given for pH paper in the *Hydrology Investigation*).
3. Record your results on the Soil pH Data Work Sheet.

With the pH pen or meter (Intermediate and Advanced Levels):

1. Calibrate the pH pen or meter with the buffer solutions of known pH following the procedure outlined in the *Hydrology Investigation* for Calibration.
2. In a cup or beaker, measure the pH of the water you are using for this protocol by placing the pH pen or meter into the water and reading the value indicated.

Figure SOIL-P-9



The pH of this soil is 6.5

3. To measure the soil pH, place the electrode of the pH pen or meter into the supernatant. See Figure SOIL-P-9.
4. Record your results on the Soil pH Data Work Sheet.

How to Measure Soil Fertility

Part 1: Preparation and Extraction

1. Fill the extraction tube from your Soil Test kit to the 30 mL line with distilled water.
2. Add 2 *Floc-Ex* tablets. Cap the tube and mix well until both the tablets have disintegrated.
3. Remove the cap and add one heaping spoonful of soil (about 5 mL).
4. Cap the tube and shake for one minute.
5. Let the tube stand until the soil settles out (usually about 5 minutes). The clear solution above the soil will be used for the nitrate nitrogen (N), phosphorus (P), and potassium (K) tests.

Note: For some soils, especially those with a high clay content, there may not be enough clear solution extracted. If more clear solution is needed, repeat Steps 1 - 5.

Part 2: Nitrate Nitrogen (N)

1. Use the pipette to transfer the clear solution above the soil to one of the test tubes in the Soil Test Kit until the tube is filled to the shoulder. (If there is not enough solution to fill the tube to the shoulder, repeat Part 1).
2. Add one Nitrate WR CTA Tablet. Sometimes the tablets may break into small pieces, so be sure that all the pieces of the tablet are added to the test tube. Cap and mix until the tablet disintegrates.
3. Rest the test tube in a cup or beaker. Wait 5 minutes for color to develop. Do not wait longer than 10 minutes.
4. Compare the pink color of the solution to the Nitrogen Color Chart in the Soil Test Kit. Record your results (High, Medium, Low, or None) on the Soil Fertility Data Work Sheet.
5. Discard the solution and wash the tube and the pipette with distilled water.
6. Repeat this procedure with the liquid from each of the soil samples. Be sure to rinse the pipette and tube with distilled water after each use.

Part 3: Phosphorus (P)

1. Use the clean pipette to transfer 25 drops of the clear solution above the soil to a clean test tube. (If there is not enough solution, repeat Part 1).
2. Fill the tube to the shoulder with distilled water.
3. Add 1 Phosphorus Tablet to the tube and cap it. Sometimes the tablets may break into small pieces, so be sure that all the pieces of the tablet are added to the test tube. Mix until the tablet disintegrates.
4. Rest the test tube into a cup or beaker. Wait 5 minutes for color to develop, but no longer than 10 minutes.
5. Compare the blue color of the solution to the Phosphorus Color Chart in the Soil Test Kit. Record your results (High, Medium, Low, or None) on the Soil Fertility Data Work Sheet.
6. Discard the solution and wash the tube and the pipette with distilled water.
7. Repeat this procedure with the liquid from each of the soil samples. Be sure to rinse the pipette and tube with distilled water after each use.

Part 4: Potassium (K)

1. Use the clean pipette to transfer the clear solution above the soil to a clean test tube until it is filled to the shoulder. (If there is not enough solution to fill the tube to the shoulder, repeat Part 1).
2. Add 1 Potassium Soil Tablet to the tube. Sometimes the tablet may break into small pieces, so be sure that all the pieces of the tablet are added to the test tube. Cap and mix until the tablet disintegrates. **Note:** This tablet may take longer to dissolve than the others.
3. Compare the cloudiness of the solution in the test tube to the Potassium Color Chart in the Soil Test Kit. Hold the tube over the black boxes in the left column, and compare its shade and cloudiness to the shaded boxes in the right column. Record your results (High, Medium, Low, or None) on the Soil Fertility Data Work Sheet.
4. Discard the solution and wash the tube and the pipette with distilled water.
5. Repeat this procedure with the liquid from each of the soil samples. Be sure to rinse the pipette and tube with distilled water after each use.

Data Submission

Record your data on the Bulk Density, Soil Particle Size Distribution, Soil pH, and Soil Fertility Data Work Sheets. More than one copy of a data work sheet may be required to describe a profile, so be sure to have extra copies. Staple together the sheets for the same soil profile so that records are kept together. Submit your findings to the GLOBE Student Data Server.

Par t Two: Soil Moisture and T emperature

Introduction

This section introduces material common to three standard protocols and a fourth optional protocol for advanced students. The protocols are all related to soil moisture and temperature. To begin, students will use a simple procedure to measure soil moisture. They will weigh a soil sample, dry it out, and weigh it again. The difference in weight is the moisture in the soil that was dried out. An optional protocol for advanced students involves the use of gypsum blocks and a soil moisture meter to take daily readings of soil water content. Two new protocols measure other important soil properties. The rate water flows into the soil (infiltration) is measured using two concentric cans. Soil temperature is measured using a short dial or digital probe thermometer.

Study Site for the Investigation

Generally, the Soil Moisture Study Site should be in the open, with no canopy overhead, and within 100 m of the Atmosphere Study Site or a supplemental Atmosphere Study Site with at least a rain gauge. Depending upon which sampling strategy is used (see below) you may need an area 10 m in diameter characterized by low slopes, homogeneous soil characteristics, natural soil moisture, and uniform sunlight conditions. It is useful to make soil characterization, soil temperature, and infiltration measurements within the same homogeneous 10 m area so that they can all be related to the soil moisture measurements. Some schools may choose a larger site with an area 10 m by 60 m which meets most of the criteria summarized above but which can include some variations in slope and other characteristics.

Your Soil Moisture Study Site(s) should be:

Unirrigated. Since we want to investigate the soil's response to the sun and natural precipitation, it is important that your site be unirrigated.

Uniform. Soil moisture can vary significantly across short distances. The challenge is to find an area where the soil moisture is representative of your site. Look for a relatively flat site that has uniform soil properties and vegetation.

Relatively undisturbed. Sample soils at least three meters from buildings, roads, paths, playing fields, and other sites where the soil may be compacted or heavily disturbed by human activity.

Safe for digging. Check with local utility companies and site maintenance staff to ensure that you do not dig into or disturb a utility cable, buried pipe, or sprinkler irrigation system. You will not be digging below one meter.

Frequency

Measure soil moisture at regular intervals, twelve times each year. Select a period during which you would normally expect the soil at your study site to undergo significant moisture changes. Observations of soil moisture should not be made when the ground is frozen . Weekly measurements during the beginning of your dry season will help predict plant growth. Monthly observations throughout the year or measurements every three weeks during a nine or ten month school year will provide insight into important seasonal variations.

Take your observations at the same time every day, and avoid early morning when dew is present. Soil moisture changes slowly so that the time of your observations is not critical. Taking all the measurements at one time of day ensures that any small daily cycles, particularly in near surface soil moisture, will not confuse your weekly to monthly observations.

Measure soil temperature once per week and on the same date and at the same location as your soil moisture measurements. If your school is not measuring soil moisture, take soil temperature measurements within 10 m of your Atmosphere Study Site following the sampling strategy for temperature given under *Collecting in a Star Pattern*. Weekly temperature measurements should be taken within one hour of local solar noon. Every three months, preferably during March, June, September and December, make soil temperature measurements every two to three hours during the daytime for two consecutive days to determine the diurnal temperature variation at your site.

Measure soil infiltration three times during the course of your annual soil moisture investigation, ideally around the beginning, middle and end of that observation period, and on the same day you sample soil moisture. If you measure soil moisture monthly, measure infiltration seasonally.

Sampling Strategies and Site Layout

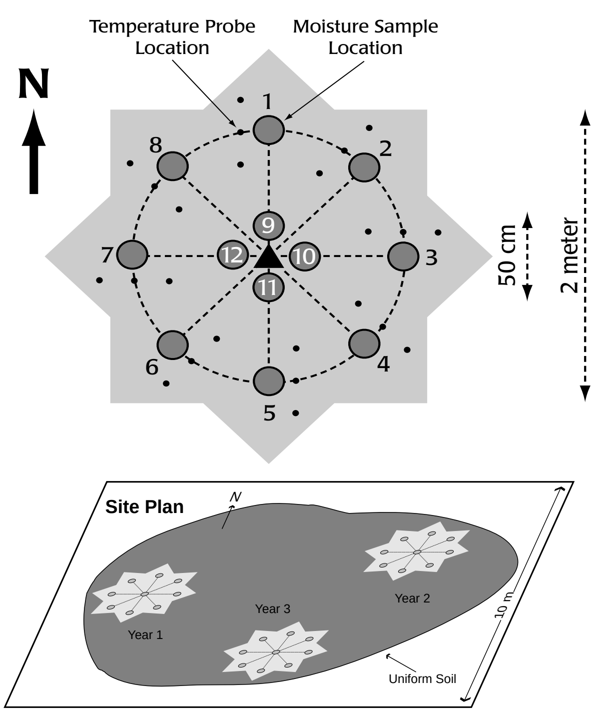
Materials and Tools

GLOBE Science Notebooks and pencils
Compass and 50 meter tape
25 cm ruler, meter stick
Trowel

Collecting in a Star Patten (6 containers)

Measurements are taken in a star-shaped pattern with samples collected each time at different locations on the star. Soil moisture samples will come from a depth of 0 to 5 cm and at a depth of 10 cm. Each time, three samples should be acquired (1 primary sample and 2 additional samples within 25 cm) for quality control purposes. Take three soil temperature measurements at depths of 5 cm and 10 cm within 25 cm of the sampling point following the *Soil Temperature Protocol.*

Figure SOIL-P-10: "Star" Sampling Pattern



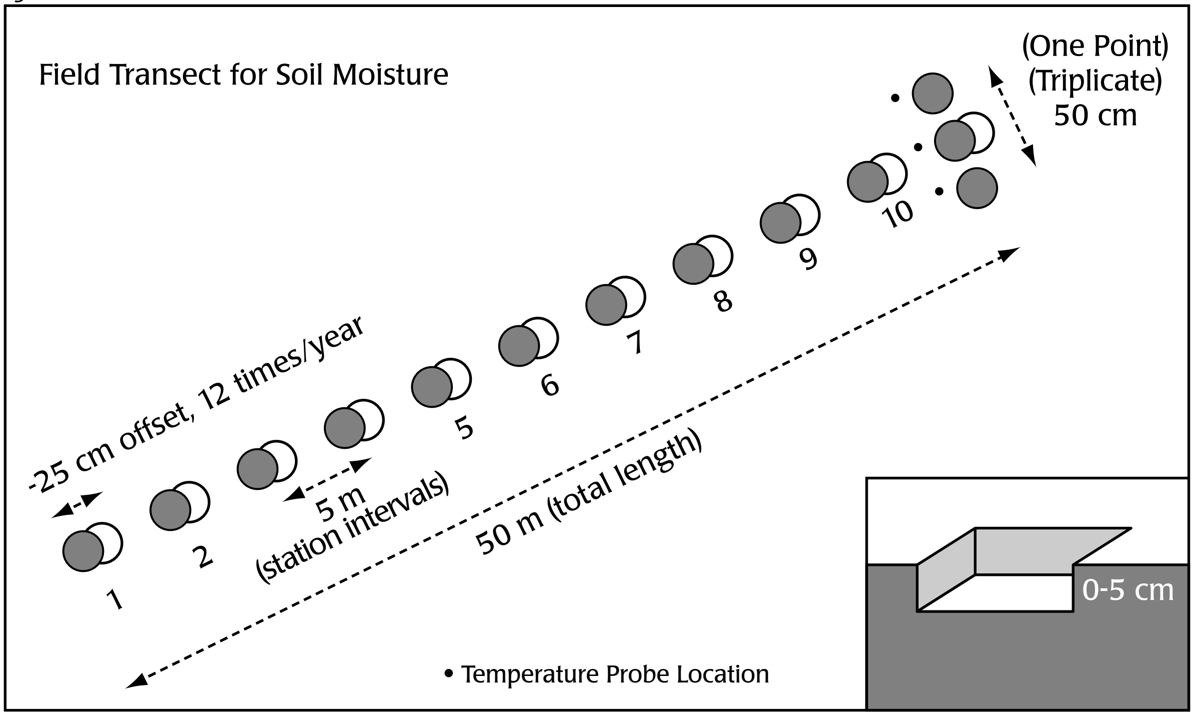
Layout a simple star two meters in diameter by using a meter stick and compass to locate four points approximately one meter north, south, east and west from a central reference marker. Locate four more points halfway between these points along an imaginary circle connecting these points. You now have eight points on your star. Four more points should be located 25 cm from the reference marker along the north - south, east - west lines. Every year, select a new reference marker within ten meters of the previous year's star and repeat this pattern. It should take less than ten minutes to collect your six soil moisture samples using a trowel.

Collecting Along a Transect (13 containers, 50 m tape or cord marked every 5 m)

Students with access to an open, natural field are encouraged to take measurements along a transect. The soil samples will come from the top 5 cm of soil. Each time, thirteen samples will be acquired - ten regular samples along the transect and one triplicate sample (1 sample along the transect plus 2 additional samples within 25 cm of the first) for quality control purposes.

Layout your transect along a straight line 50 meters long across an open area within 100 m of a rain gauge, if possible. Measure soil moisture every five meters along this line. Place a permanent flag or marker at the ends of your transect. Use the knotted cord or a measuring tape to locate these sampling points. Orientation does not matter, but please record the orientation as a comment on the Study Site Work Sheet and report it on the Study Site Definition Data Entry Sheet. The next time you sample the transect, shift each of your data collection points 25 cm to avoid the previously disturbed area. It might take an hour to layout and sample a transect, especially if students are sharing equipment and observing other surface and soil characteristics.

Figure SOIL-P-11



Collecting at Different Depths (5 containers, auger)

Students take measurements in a star-shaped pattern, collecting samples each time at different locations on the star. Soil samples from all five depths will be collected from the same hole. Use a trowel to sample from the top 5 cm and an auger to sample at the four deeper depths (10, 30, 60, 90 cm). Unlike the previous two sampling strategies that are designed strictly for open areas, this one can be done in the open or under a canopy, depending upon what data comparisons you wish to make (e.g. comparing soil moisture to evaporation or tree growth). Layout a star pattern as described above to locate the sampling holes around a central reference marker. If your auger strikes an obstruction, offset by 25 cm and try again. Depending upon conditions, a hole 90 cm deep might take 30 minutes to auger and sample.

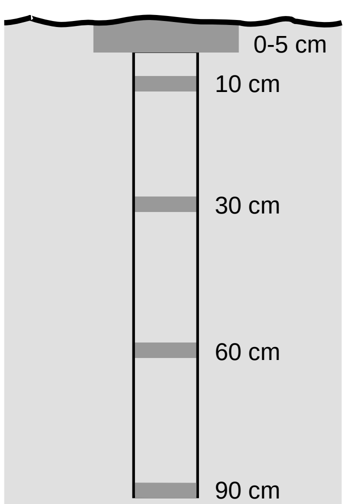


Figure SOIL-P-12

Advanced students in areas where soils are not strongly acidic are encouraged to consider using the *Optional Gypsum Block Soil Moisture Protocol*.

Gravimetric Soil Moisture Protocol

Purpose

To measure the water content of the soil

Overview

Soil moisture samples are collected following one of three sampling strategies. In each case, there are three basic steps:

1. collecting soil samples
2. weighing, drying, and reweighing soil samples
3. data submission

Time

Up to 15 minutes to collect each sample, 15 minutes for first weighing, 15 minutes for second weighing, samples dry in oven overnight

Frequency

Twelve times per year, at regular intervals (weekly to monthly)

Level

All

Key Concepts

Soil holds moisture.

Soil moisture increases after precipitation, and the amount of this increase depends on many factors.

Soil moisture decreases under dry, sunny conditions, and the rate of soil drying also depends on many factors.

Skills

Sampling soil

Using a balance

Recording data

Materials and Tools

GLOBE Science Notebooks and pencils

Soil Moisture Data Work Sheet (Star or Transect)

Trowel or appropriate auger

5-13 soil collection containers (soil sample cans, small glass jars with tight-fitting lids, etc.)

Adhesive tape and pens with which to label the soil cans

Soil drying oven

Thermometer (capable of measuring to 110° C)

Balance or scale with 0.1 g sensitivity

Hot pad or oven mitt for removing cans of soil from ovens

Meter stick

Preparation

Locate the soil moisture site.

Decide upon the sampling frequency and strategy.

Assemble the necessary materials.

Prerequisites

It is useful to have a rain gauge nearby and to have performed the *Soil Characterization Protocols* on your Soil Moisture Study Site.

How to Collect Soil Moisture Samples

Preparation for Collecting Samples

1. Review procedures, site sampling strategy, and layout.
2. Label each can with a unique identification number.
3. Record the location of the site and site description.
4. Locate the sampling point.

Procedures for Star and Transect Sampling

1. Note your surface cover type. Is it short grass (<10 cm), long grass, or bare soil? Scrape or pull this away. Note if there are any trees overhead or nearby.
2. Dig a hole 10 cm in diameter down to 5 cm. Leave this soil loose in your hole.
3. Sort out and remove any rocks or pebbles larger than a pea (about 5 mm) and remove any worms, grubs, or other animals.
4. Fill your soil collection container about 3/4 full with approximately 100 g of soil.
5. Number the container and record the date, time, depth and can number on your Soil Moisture Data Work Sheet.
   For Transect, skip to Step 9.
6. Remove the soil down to a depth of about 8 cm.
7. Dig the soil in the hole down an additional 4 cm leaving this soil in the hole.
8. Repeat steps 3, 4, and 5 for this 4 cm deep soil layer.
9. Carefully return remaining soil to the hole.
10. Seal the container and store away from heat or sunlight for transport back to the lab or classroom.
11. Take one soil temperature measurement within 25 cm of each soil sampling point at depths of 5 and 10 cm following the *Soil Temperature Protocol.*

Procedures for Depth Sampling

1. Take a sample of the top 5 cm of soil following Steps 1 - 5 as given for *Star and Transect Sampling.*
2. Auger a hole down to just above the first target depth (10 cm).
3. Use the auger to obtain a soil sample of approximately 100 g.
4. Collect the soil sample centered at the target depth.
5. Sort out and remove any rocks or pebbles larger than pea size (about 5 mm) and remove any worms, grubs, or other animals.
6. Fill a soil container about 3/4 full (about 100 g).
7. Number the container and record the date, time, depth and the container's number on your data sheet.
8. Seal the container tightly and store it away from heat or sunlight.
9. Repeat steps 1 - 8 at each depth (30, 60, 90 cm) using the same hole.
10. Carefully return the remaining soil into the hole.
11. Take three soil temperature measurements at depths of 5 cm and 10 cm within 25 cm of the sampling point.

How to Weigh and Dry the Samples

Preparation for Weighing and Drying Samples

1. Preheat the oven.
2. Calibrate the balance with a standard weight to ensure its accuracy.
3. Record the weight of the standard to the nearest 0.1 g in your GLOBE Science Notebook. The weight must be within 0.25 g of the previously recorded standard weight.

Weighing and Drying Procedure

1. Remove any tape from the can that contains the sample soil and uncover the sample.
2. Weigh the soil collection container with the soil sample in it. This is the *wet weight.*

3. Record the date and time at which the sample was collected, the container's number, and the wet weight to nearest 0.1 g on your Soil Moisture Data Work Sheet.
4. Dry the soil by placing the uncovered can in a drying oven using the following minimum conditions:

   Ventilated drying oven, 95° to 105° C, 10 hours,

   Dehydrating oven, 75° to 95 °C, 24 hours

   Microwave oven, high power, microwave safe container only, repeated 5 minute intervals until the sample(s) do not change in weight by 0.25 g from one drying to the next.
5. Remove the can from the oven with the hot pad or oven mitts. Let it cool for five minutes.
6. Re-weigh the soil collection container with the soil in it to obtain the *dry weight*.

   Note: If you are concerned that a sample is not totally dry, remove it from the oven, weigh it, and return it to the oven for 10 hours. If the weight does not decrease by 0.25 g, then it is dry.
7. Record the drying time, the type of drying oven used, and the dry weight to the nearest 0.1 g on your Soil Moisture Data Work Sheet. Calculate the water weight by subtracting the dry weight from the wet weight.
8. Empty the soil out of each container and wipe the can clean with a paper towel.
9. Weigh the dry, empty soil collection container to determine the container weight.
10. Record the container weight to the nearest 0.1 g on your Soil Moisture Data Work Sheet, and calculate the dry soil weight by subtracting the container weight from the dry weight.
11. Calculate the Soil Water Content by dividing the water weight by the dry soil weight, and record your result on the Soil Moisture Data Work Sheet.
12. Repeat steps 1 - 11 for each soil sample.

Data Submission

Report the following information to the GLOBE Student Data Server:

- Date and time of sampling
- Container number
- Depth (in cm)
- Wet weight (in grams)
- Dry weight (in grams)
- Container weight (empty, in grams)
- Drying method (select one of: 95-105 C oven, 75-95 C oven, Microwave)
- Average drying time (in hours and/or minutes)
- Current conditions: Is the soil saturated? (select either YES or NO)
- Station spacing of your transect, if used

Students can calculate the soil water content (SWC) defined below, or let the GLOBE Student Data Server make this calculation. Making this calculation and entering it on the Data Entry Sheet is helpful as a quality control check. If the SWC calculated by students is different by more than 1% from the value calculated by GLOBE, a warning message will appear. In this case, students should make sure that the weights were entered correctly and check their calculations.

In addition, please enter the following information using the Define a Soil Moisture Study Site Data Entry Sheet:

- GPS location of the study site (the center of the star, gypsum block hole, or reference marker at one end of the transect)
- Distances and directions to other related sites (rain gauge, max-min thermometer, closest soil characterization sample location)
- How would you describe the surface of your site? Select one: natural, plowed, graded, backfill soil, compacted soil, or something else (other)
- How would you characterize the surface cover? Select one, Primarily: bare soil, short grass (<10 cm), or long grass (>10 cm)

- How would you describe the canopy cover? Select one: Open, Some trees within 30 m or Canopy overhead (answer this question assuming growing season conditions)
- Soil classification (using the Soil Characterization Data Entry Sheet for these data)

  Describe and report as many soil characteristics as possible following the protocols in *Part One* of this investigation.
- Land Cover classification

  Classify your Soil Moisture Study Site as instructed in the *MUC System Protocol* and report the Level 4 MUC code and land cover name.

Optional Gypsum Block Soil Moisture Protocol

Purpose
To measure the water content of the soil based on the electrical resistance of gypsum blocks

Overview
The Gypsum Block Protocol consists of:

1. installing gypsum blocks at 10, 30, 60, and 90 cm depths
2. reading the soil moisture meter
3. calibrating the gypsum blocks
4. creating a calibration curve

Time
10 minutes per day

Initial calibration requires doing the Gravimetric Soil Moisture Protocol for the 30 cm depth about 20 times over six to eight weeks.

Level
Advanced

Frequency
Daily

Re-installation and calibration of gypsum blocks should be done annually.

Key Concepts
A Gypsum block's electrical resistance is related to soil moisture and is a function of its wetness.

Local conditions affect the saturation of gypsum blocks and requires us to calibrate them.

Soil moisture increases after precipitation.

The amount of increase in soil moisture after precipitation depends on many factors.

Soil moisture decreases on dry, sunny days.

The rate of soil drying depends on many factors.

Skills
Sampling soil

Using a balance

Using a soil moisture meter

Recording data

Materials and Tools
Auger

Meter stick

Four gypsum blocks

Four 10 cm long x 7.6 cm diameter PVC tube or tin cans for wire holders at the surface

Two 4-L soil holding/mixing buckets

Water for making mud balls (1 L)

One 1 m x 2 cm PVC guide tube

Soil packing stick (e.g. an old broom handle)

GLOBE Science Notebooks and pencils

Soil moisture meter

Graph paper

Calculator

Materials for the *Gravimetric Soil Moisture Protocol*

Preparation
Locate the soil moisture site.

Determine and report the requested soil moisture site metadata.

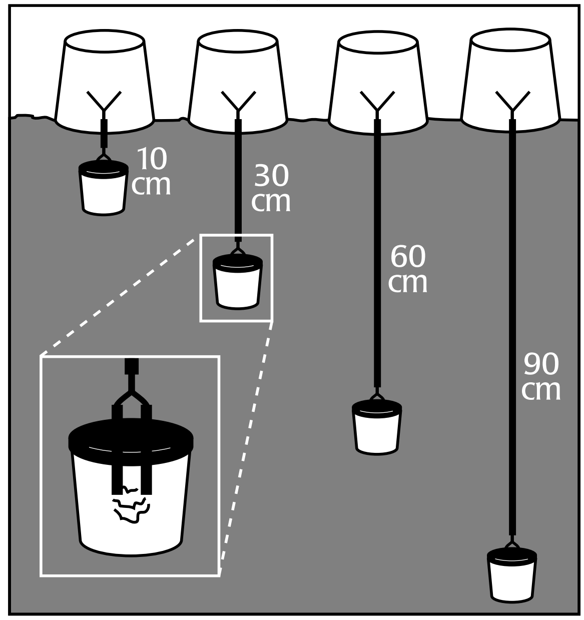
Collect the tools and materials.

Prerequisites
It is useful to have a rain gauge nearby and to have performed the Soil Characterization protocols at your Soil Moisture Study Site.

Installation of Gypsum Blocks

1. Place the gypsum blocks into a container of water and soak for 5 minutes.
2. Auger a hole to the appropriate depth for each gypsum block sensor (10, 30, 60 and 90 cm). A soil auger works like a cork screw - simply lean on the handle as you turn it. It is best to remove the auger bucket from the hole after each 360° turn and clean the soil out of the bucket. If you fill it too full, it will be very difficult to remove the soil. Place the extracted soil in a large pail to keep the site clean. The four holes should be placed next to one another in sequence to reduce potential confusion while taking readings and recording data.
3. Put two large handfuls of the soil extracted from the hole into a small bucket or similar container. Add a small amount of water and stir to create a mud ball. The mud ball should stick together. Remove any rocks.
4. Drop the mud ball to the bottom of the hole. Make sure it reaches the bottom.
5. Place the wire lead from one of the sensors through the PVC guide tube.
6. Grab the end of the lead and pull the sensor up tight against the end of the pipe. Lower the sensor into the hole while holding it against the end of the pipe. Holding the wire lead tightly at the top of the pipe, gently push the pipe down to seat the sensor in the mud at the bottom of the hole. **Note:** Since it is difficult to pack soil tightly around the sensor, the purpose of the mud is to establish good contact between the sensor and the soil particles.
7. Hold the sensor in place with the pipe while you begin to backfill the hole. Add just a few handfuls of soil and gently tamp with a broom stick or similar pole. Then add a little more soil and remove the pipe as you tamp. Continue adding soil a few handfuls at a time and tamping firmly as you backfill the hole. Hold on to the wire lead as you backfill so that it will come straight to the surface.

Figure SOIL-P-13: Installed Gypsum Blocks Configuration



8. Place a short piece (about 10 to 20 cm long) of PVC pipe, tin can, or coffee can (with the top and bottom removed) around the wire lead at the surface to protect it and make it more visible to anyone walking in the vicinity.
   8.1. First, label the pipe or can with the appropriate sensor depth.
   8.2. Put the wire through the pipe or can and press the pipe or can 2 to 5 cm into the soil to keep it in place. Do not cut the wire, but wind up the free end extending out of the ground and place it in the pipe or can to keep it out of the way between measurements.
   8.3. A small empty can (soup, etc.) should be inverted over the end of the PVC pipe to keep the rain out.
9. Repeat the above steps for each sensor.

Do not report measurements for a week after installation. The sensors require at least one week to equilibrate to natural conditions. The wire leads are fragile, especially where they connect to the meter. If the end of the wire leads to the gypsum blocks break, peel back the wire insulation and make new leads. It is important to leave enough wire above the ground for this.

Reading the Soil Moisture Meter

Congratulations! Your gypsum blocks are installed. Wait at least one week before beginning to take data which you report to the GLOBE Student Data Archive. After this, monitor your gypsum blocks daily for soil moisture variations. This is the fun and easy part of this investigation. Do not monitor the blocks when the ground is frozen.

Preparation

Test the soil moisture meter to ensure it is functioning properly according to the manufacturer's instructions. Do this before each use.

How to Make a Soil Moisture Reading

1. Obtain the reading for each gypsum block.
   1.1. Connect the soil-moisture meter to the wire leads of the gypsum block located at the 10 cm depth.
   1.2. Push READ button. Wait for the meter to reach a constant value - it should not be negative.
   1.3. Record the date, time, current soil conditions (CC's), and soil moisture meter reading on the Daily Gypsum Block Data Work Sheet in the appropriate depth column.
   1.4. Disconnect the meter and store the wire leads.
   1.5. Replace the cover over the PVC pipe.
   1.6. Repeat steps 1.1 - 1.5 for each of the remaining gypsum blocks (30, 60, 90 cm).
2. Report all four meter readings to the GLOBE Student Data Server.
3. Convert each meter reading to soil water content using the calibration chart.

How to Use the Daily Gypsum Block Data Work Sheet

There are numbers 1 to 0 in the far left column. Please keep a running count of your measurements by adding a tens digit as you accumulate more data. This allows someone reviewing your data sheets to ascertain if any pages are missing. There is also space to plot your data in the field as you collect it. You would normally expect gradual transitions except for the rapid increase in soil moisture after a rain.

Calibration of Gypsum Blocks

The gypsum blocks must be calibrated so that the meter reading you make can be related to soil water content (SWC). This process can take 6-8 weeks, depending upon how quickly your soil moves through its full drying cycle. Rather than calibrate your gypsum blocks at every depth, we have adopted a policy of basing each calibration on observations made from the 30 cm sensor. Technically, this assumes your soil profile is uniform and your gypsum blocks are identical. It takes about 30 minutes to complete the steps below. You may calibrate your gypsum blocks at 10, 60, and 90 cm depths using the same procedure if you wish.

What To Do and How To Do It

1. Take a soil meter reading from the 30 cm gypsum block sensor.
2. Select a random location within 5 m of the gypsum block hole.
3. Clear surface debris.
4. Auger to 30 cm and collect a 100 g sample centered at this depth. Place the soil sample in a container and number the container.
5. Backfill the hole and replace the surface cover.
6. Record the date, time, depth and container number.
7. Follow the instructions for *Weighing and Drying The Samples* found in the *Gravimetric Soil Moisture Protocol* and make a note of your drying method and average drying time.
8. Record on the Annual Gypsum Block Calibration Data Work Sheet the date and time of your measurement, the wet, dry, and container weights and the soil moisture meter reading that you obtained. There is also space to calculate soil water content (SWC).
9. Repeat steps 1 - 8 about twenty times as the soil moves through one or two complete drying cycles. Wait until your meter reading changes 5% before collecting another gravimetric sample. Re-install and recalibrate your gypsum blocks once a year.

Creating a Calibration Curve

How to plot a calibration curve

1. Complete the Annual Gypsum Block Calibration Data Work Sheet using the following formula to calculate the values for Soil Water Content (SWC) for each row of the Work Sheet.

$$SWC = \frac{(\text{wet weight - dry weight})}{(\text{dry weight - can weight})} \times 100$$

Remember:

wet weight = wet soil + can

dry weight = dry soil + can

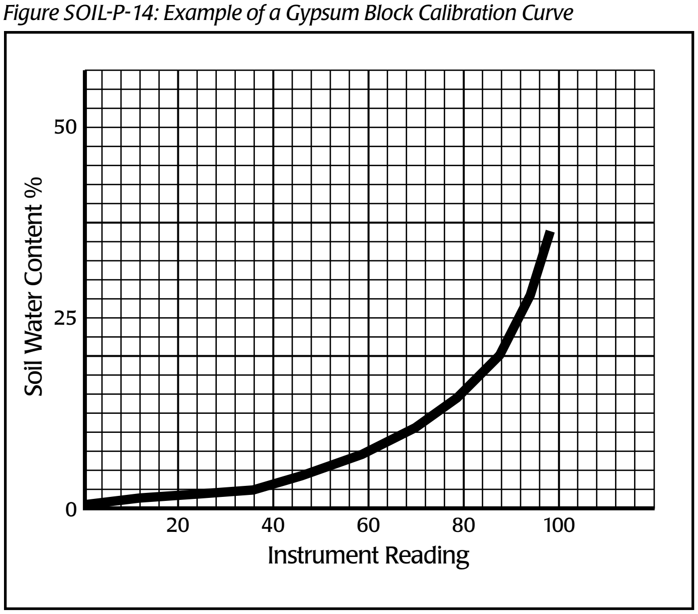
2. Create a graph in which you plot all the soil water content data collected on the Y-axis and all the corresponding soil moisture meter readings on the X-axis. Draw or calculate the *best-fit quadratic curve* through your data pairs, which should span a broad range of soil moistures. This will be your calibration curve, which you will use to convert other meter readings to soil water content.

If you have any questions about creating your calibration curve or if you need any assistance with the curve, the principal investigator for the *Soil Moisture Investigation* is glad to provide answers and assistance and can be contacted at the addresses given in the *Welcome Section*.

When you have finished determining your calibration curve, please mail or email a copy of your curve and of your corresponding Annual Gypsum Block Calibration Data Work Sheet to GLOBE Student Data Archive at the address given in the *Implementation Guide*.

During the year, if you get readings either higher or lower than any of the readings on your Data Work Sheet, take a gravimetric sample, and use the values you measure for this sample to extend your calibration curve. Send a copy of your revised calibration curve and extended Annual Gypsum Block Calibration Data Work Sheet to the GLOBE Student Data Archive.

Figure SOIL-P-14: Example of a Gypsum Block Calibration Curve



30 cm

Date	Reading	SWC
2/4/97	42	7
2/25/97	17	3
3/6/97	96	35
3/8/97	91	25
3/18/97	70	14

Infiltration Protocol

Purpose

To determine the rate at which water soaks into the ground as a function of time

Overview

Two nested cans are pushed into the soil and water is added to both to a depth of at least 5 cm. The time it takes water to drop a fixed 2 - 4 cm distance is recorded and the measurement is repeated. Infiltration measures how easily water moves vertically through the soil and this can indicate how flood-prone an area is.

Time

One class period to build and test the double-ring infiltrometer

45 minutes or one class period for the measurement

This protocol can be done while samples are collected for the *Gravimetric Soil Moisture*

Level

All

Frequency

Three or four times a year at the Soil Moisture Study Site

One time at a Soil Characterization Sample Site

In all cases three sets of measurements should be taken within a radius of 5 m.

Key Concepts

Infiltration rate changes depending upon the level of soil saturation.

If water is not stored in the ground, it must evaporate or runoff and may pool on the surface for a time.

Skills

Building an infiltrometer

Testing

Organizing

Observing

Monitoring time intervals

Recording data

Analyzing data

Materials and Tools

Two metal rings the smaller with a diameter of 10 - 20 cm and the other with a diameter 5 - 10 cm larger (Coffee cans work!)

Buckets or other containers to transport a total of at least 8 L of water to the site

Ruler

Waterproof marker

Stop watch or watch with a second hand

Block of wood

Hammer

Three soil sample containers suitable for soil moisture measurement

Grass clippers

Funnel

Prerequisites

None

Background

Infiltration rate is determined by measuring the time it takes the level of water sitting on a soil to drop a fixed distance. This rate changes with time as the soil pore space fills with water and reaches a steady rate, characteristic of water flow through your soil when it is *saturated*. There are three flow regimes you might encounter:

Unsaturated flow- the initial flow rate is high as the dry soil pores fill with water.

Saturated flow- the flow rate is steady and water moves into the soil at a rate determined by soil texture and structure.

Ponding - the flow rate approaches zero when the ground becomes totally saturated and is no longer able to conduct water through its pores.

Preparation

Site selection

Select a location within 2 - 5 m of the Soil Moisture Study Site or of a Soil Characterization Sample Site. Be careful that you do not leave a hose running where the water will flow over your soil moisture sampling points!

Construct a Dual Ring Infiltrometer

Cut the bottom out of your cans.

Use a permanent waterproof marker or paint to partially shade a ring on the inside of the smaller can to use as a timing reference mark. The width of the band or ring should be 20-40 mm and centered roughly 9 cm from the bottom of the can. Many cans have impressed ribs that make good reference marks but it is still necessary to mark them for good visibility.

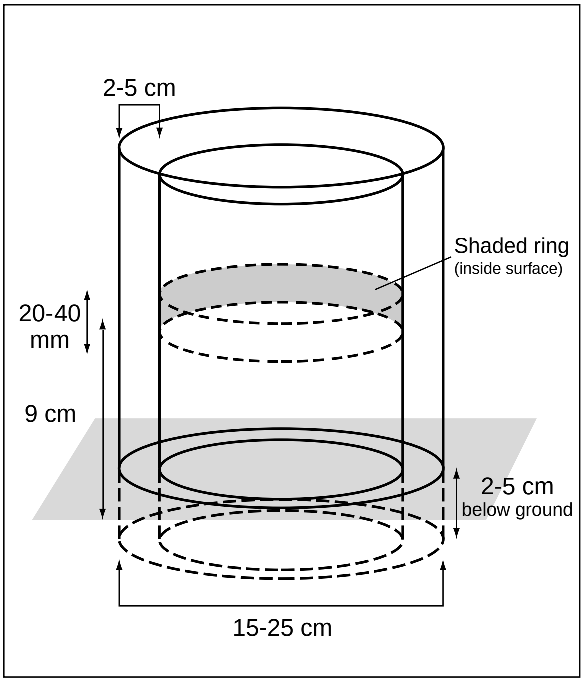
Measure and record the width of your reference band (in mm).

Measure and record the widths of your inner and outer rings (in cm).

Timing

You can use either a stop watch or a watch with a second hand to time the water flow into the soil. When using a stop watch, start it as water is first poured into the inner ring and read elapsed time from it for each start time and end time.

Figure SOIL-P-15: Double-ring infiltrometer



Practice

Have students practice this protocol, including the timing, so that they become comfortable making the measurements at a site where there is easy access to water and at a time when they can start over and do not have to complete a full 45 minute set of measurements. If students practice in a sandy location, the infiltration time intervals will be shorter and they will get more chances to make measurements.

How to Measure Infiltration

1. Clip any vegetation (grass) to the ground surface and remove all loose organic cover over an area just larger than your largest can. Try not to disturb the soil.
2. Starting with the smaller can, twist the cans 2 - 5 cm into the soil. A hammer may be used to pound the can into the surface. If you must use a hammer, a block of wood should be used between the hammer and the top of the can to distribute the force of the hammering. Do not hammer so hard that the can crumples.

3. Measure the height above ground level of the bottom and top of the band you marked on the inside of the smaller can.
4. As quickly as possible, do the following using a team of 3 - 4 students:

   4.1. Pour water into both rings, and maintain a level in the other ring approximately equal to the level in the inner ring. Note that the water level in the outer ring tends to drop more quickly than that of the inner ring.

   4.2. Pour water into the inner ring, to just above the upper reference mark.

   4.3. Start the stopwatch or note the time to the second and record it on the Infiltration Data Work Sheet.

   Note: The outer ring should not be leaking water to the surface around its rim. If it is, start over in another location, push the outer ring deeper into the soil or pack mud around its base.
5. As the water level in the inner ring reaches the upper reference mark, record the elapsed time as your start time.
6. During the timing interval, keep the water level in the outer ring approximately equal to the level in the inner ring, but be careful not to pour water into the inner ring (using a funnel can help) or to let either ring go dry.
7. As the water level in the inner can reaches the lower reference mark,

   7.1. Record the time as your end time.

   7.2. Figure the time interval by taking the difference between the start and end times.

   7.3. Pour water into the inner ring to just above the upper reference mark. Raise the water level in the outer ring so that they are approximately equal.
8. Continue repeating steps 5 - 7 for 45 minutes or until two consecutive interval times are within 10 sec. of one another.
9. Some clays and compacted soils will be impervious to water infiltration and your water level will hardly drop at all within a 45-minute time period. In this case, record the depth of water change, if any, to the nearest mm. Record the time at which you stopped your observations as the end time. Your infiltration measurement will consist of a single data interval.
10. Remove the rings. WAIT FIVE MINUTES.
11. Measure the near-surface (0 - 5 cm depth) soil moisture from the spot where you just removed the rings. Follow the *Gravimetric Soil Moisture Protocol*.
12. Make two other infiltration measurements within a 5 m diameter area, either at the same time using other groups or over several days (if it does not rain and change near-surface soil water content). It is not critical that multiple runs have the same number of reading sets, but do not submit runs that are incomplete (e.g. A run that was cut short due to lack of time). If you make more than three sets of measurements, submit your three best sets.

Data Analysis and Presentation

Infiltration rate is found from the distance that the water level decreased divided by the time required for this decrease. For your GLOBE measurements this is equal to the width of your reference band divided by the difference between the start and end times for an interval.

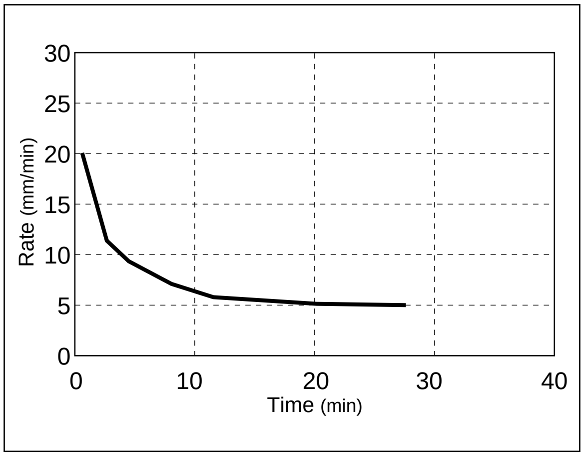
Use the Infiltration Data Work Sheet to record and help calculate the values needed to plot your results. The flow rate we observe for each timing interval is really the average value during that interval. It is best to plot that flow rate at the *midpoint* of the interval times. Infiltration should decrease with time and it is important that you keep track of the *cumulative* time since water was first poured into the inner ring. Look over the table and graph below and make sure that you can use the formulas on the Data Work Sheet to calculate these values before analyzing your own data.

Figure SOIL-P-16
Infiltration into Jim's Garden

Water Level Change = 20 mm

Time							Flow
Start		End		Interval	Midpoint	Cumulative	Rate
[min]	[sec]	[min]	[sec]	[min]	[min]	[min]	[mm/min]
31	00	32	00	1.00	31.50	0.50	20.0
32	30	34	15	1.75	33.38	2.38	11.43
34	30	36	45	2.25	35.62	4.62	8.89
37	15	40	00	2.75	38.62	7.72	7.27
40	45	44	00	3.25	42.38	11.38	6.15
44	15	47	45	3.50	46.00	15.00	5.71
48	15	52	00	3.75	50.12	19.12	5.33
52	15	56	15	4.00	54.25	23.25	5.00
56	30	00	30	4.00	58.50	27.50	5.00

Figure SOIL-P-17: Infiltration



Soil Temperature Protocol

Purpose

To measure near-surface soil temperature
To detect diurnal changes in soil temperature
To learn about the insulating capabilities of the soil

Overview

Soil Temperatures at 5 and 10 cm depths will be measured using a probe thermometer. Soil temperature is a function of climate, soil, soil moisture, depth and geographic setting. This protocol collects data to explore these interactions.

Time

10-15 minutes per measurement set
(6 probe measurements)

Level

All

Frequency

Weekly: three measurements each at 5 and 10 cm depths

Seasonally: one measurement each at 5 and 10 cm depths every 2 to 3 hours during the daytime on two consecutive days

Key Concepts

Soil is an insulating layer.
Soil temperature varies with depth, soil moisture, and air temperature.
Soil temperature varies less than air temperature.

Skills

Reading dial scales
Field *sampling*
Observing related phenomena
Graphing temperature cycles

Materials and Tools

Dial or Digital probe thermometer
12 cm finishing nail and hammer
A wooden block with 6 mm diameter hole through it
Calibration thermometer

Preparation

None

Prerequisites

None

Site Selection and Timing

Make measurements adjacent to your Soil Moisture Study Site, or if this is not possible, within 10 m of your Atmosphere Study Site. Study the figures of the star or transect sampling patterns described in the *Sampling Strategies* and *Site Layout* sections which illustrate acceptable sampling locations. If you are making these measurements at your Atmosphere Study Site, follow the sampling pattern and site layout for the Star Pattern.

1. Select a relatively flat sunny area.
2. Try to find an area with uniform characteristics across an area having a diameter of 5 m.
3. The ground should not be compacted but can be covered with litter or grass.
   - Make a note on the Data Work Sheet if it has rained in the past 24 hours.

When making measurements on consecutive days, try to make your readings on days with similar weather conditions and for soil conditions that are typical for the week you are making them. Try to make diurnal readings around the middle of March, June, September, and December.

Preparing for the Field

Your thermometer should be most sensitive to temperature changes about 2 cm from the tip because of the length of the temperature sensor inside the probe. To take measurements at 5 and 10 cm depths, the thermometer will have to be pushed 7 and 12 cm into the ground.

Drill a hole in a wooden block so that when the soil thermometer is pushed all the way into this hole 7 cm of your probe extends beyond the bottom of the block. This will help students maintain a uniform depth for the 5 cm depth measurements.

Get a nail that is the same length and diameter as your thermometer probe or cut a nail to this length.

Calibration:

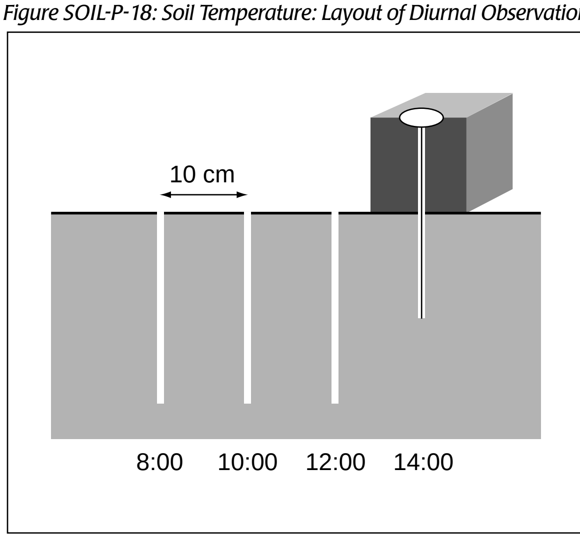
Check the accuracy of your probe every three months. This is particularly important if you are using more than one thermometer, as differences or biases between two thermometers will make your data impossible to interpret. Follow this calibration procedure:

1. Use the calibration thermometer from the Atmosphere Investigation as a calibration standard.
2. Place your thermometers in water at room temperature; record their temperature readings after 2 minutes.
3. There should be less than 2° C difference between your thermometer readings and the calibration thermometer.
4. Follow the manufacturer's directions to reset dial-type thermometers, if your differences are greater than this.

How to Measure Soil Temperature

1. **Make a pilot hole to 5 cm.** Insert the nail through your wood block and push it to 2 cm above the top of the block. If the ground is so hard you have to use a hammer, then complete the pilot hole to its full depth. Remove the nail using a twisting motion. If the ground cracks and bulges up as you remove the pilot nail, offset 25 cm and try again. Try to minimize the amount you disturb the soil.
2. **Insert the thermometer to 7 cm.** Insert the thermometer through your block. Gently push and twist the thermometer until the head is resting on the block. Do not force it as this will damage your instrument.
3. **Read the soil temperature at 5 cm.** Wait at least 2 minutes; read the thermometer. Wait another minute, and reread the thermometer. Repeat until consecutive readings are within 0.5 - 1.0° C of each other. Record this value on the Soil Temperature Data Work Sheet.
4. **Remove the thermometer and the block.** Use a twisting motion - try not to disturb the soil.
5. **Repeat steps 1-4 without the wood block.** Gently push and twist your thermometer fully into the ground using the same hole as before. Instead of depths of 5 and 7 cm, use depths of 10 and 12 cm, respectively.
6. Report your measurements to the GLOBE Student Data Server on the Soil Temperature Data Entry Sheet.

Figure SOIL-P-18: Soil Temperature: Layout of Diurnal Observations



Weekly Measurements

Take three sets of soil temperature measurements adjacent to your current soil moisture star pattern sampling location or next to your Atmospheric weather shelter at 5 and 10 cm depths. Complete these measurements within 1 hour of local solar noon and within a period of 20 minutes. Record your time to the nearest 10 minutes (e.g. if you take the 5 cm reading at XX:06, select the next 10 minute mark, XX:10, as your time of observation.

Diurnal/Seasonal Measurements

Take diurnal temperature measurements every three months, preferably during March, June, September, and December. Repeat the measurements every 2 to 3 hours on two consecutive days. Try to take at least 5 readings per day. Offset each new reading by at least 10 cm. See Figure SOIL-P-18. Read the current temperature at your Atmosphere Investigation Instrument Shelter and record it in your GLOBE Student Notebook each time you measure soil temperature.

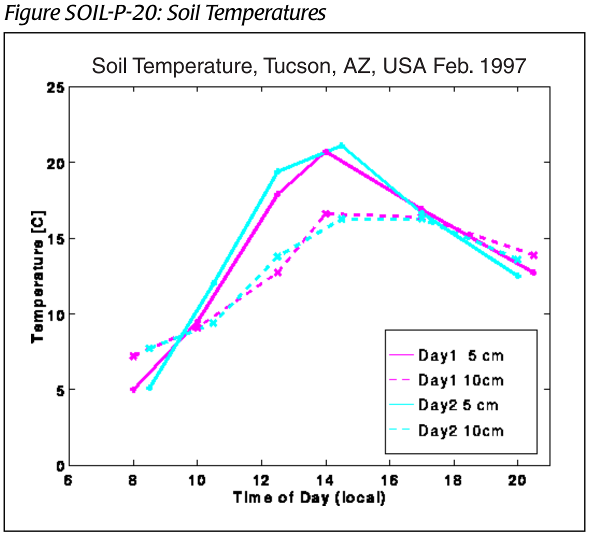
Data Analysis and Presentation

Construct a table in your GLOBE Student Notebook similar to the one below for recording your results or use the Soil Temperature Data Work Sheet. Plot the data using Figure SOIL-P-20 as a guide.

Figure SOIL-P-19: Soil Temperatures Tucson, AZ, USA

	2/12/97			2/13/97		ND=no data
Local Time	5 cm	10 cm	Local Time	5 cm	10 cm	Air Temp
8:00	5.0	7.2	8:30	5.1	7.7	ND
10:00	9.5	9.1	10:30	12.0	9.4	ND
12:00	17.8	13.0	12:30	19.4	13.8	26.2
14:30	20.6	16.5	14:30	21.1	16.3	ND
17:00	16.8	16.3	17:00	16.7	16.3	ND
20:30	13.0	13.9	20:00	12.5	13.6	ND

Figure SOIL-P-20: Soil Temperatures



Just Passing Through

Beginning students are introduced to the basic concepts of how water passes through soil in an activity which illustrates the scientific method. More advanced students investigate the effects of soil characteristics on water infiltration and the chemistry of water that has passed through soil.

From Mud Pies to Bricks

Introduces the various particle sizes found in soils and the properties which each contributes to the soil character.

Soil and My Backyard

Students collect, describe and compare soils from their own backyards.

A Field View of Soil and Soil Moisture - Digging Around

Students discover that soil properties such as moisture and temperature can vary considerably across a single landscape.

Soils as Sponges: How Much Water Does Soil Hold?

Students explore soil moisture by weighing and drying sponges and then they explore their soil samples in the same way.

Soil: The Great Decomposer

Students simulate environmental conditions in order to determine which are the key factors in the decomposition of organic material in soil.

Making Sense of the Particle Size Distribution Measurements

Students use the data from the this protocol to determine the texture of soil horizons.

The Data Game

Teams of students play a game in which they gather data and distort the values of certain measurements. They then estimate the values of the measurements taken by other teams and try to detect their errors.

Just Passing Through (Beginner Version)

Purpose

To develop an understanding of how water flows through soils and of how the water changes as it goes through

Overview

Students time the flow of water through different soils and observe the amount of water held in these soils. They will also observe the filtering ability of soils by noting the clarity of the water before and after it passes through the soil.

Time

One class period

Level

Beginning

Key Concepts

Water flows through soil.
Soil holds water.
Soil properties affect flow rate and water holding capacity.

Skills

Asking questions
Developing hypotheses
Testing hypotheses
Observing results
Analyzing results
Drawing conclusions
Timing
Measuring pH

Materials and Tools

(for each team of 3-4 students)

Clear 2 liter bottle
Three 500 mL beakers or similar size clear containers marked off in cm to pour and catch water
Soil sample (Bring in 1.2 L samples of different types of soil from around the school or from home. Possibilities include top soil (A horizons), subsoils (B horizons), potting soil, sand, soils that are compacted, soils with grass growing on top, soils with clearly different textures)
Fine window screen or other fine mesh that does not absorb or react with water (1 mm or less mesh size)
Water
Clock or timer
Note: Smaller containers may be used if desired as long as the soil container sits firmly on the water catchment container. Reduce the amounts of soil and water - but remember that it is important for all students to start with the same amount.
For more advanced beginners:
pH paper, pen, or meter

Preparation

Discuss, with students, some of the general characteristics of soils or do *Soil in My Backyard* or the *Soil Characterization Protocols*.

Prerequisites

None

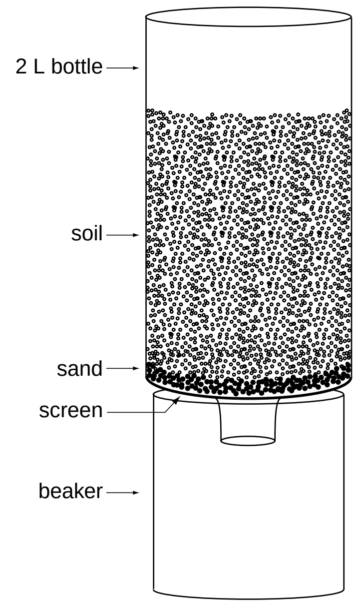
Background

What happens to water when it passes through soil depends on many things such as the size of soil particles (texture and particle size distribution), how the particles are arranged (structure), how tightly they are packed (bulk density), and the attraction between the soil particles and the water. Some types of soil let water flow in quickly, then hold the water inside the soil like a sponge. This might give plants a better chance of using some of that water. Other types of soil may let the water go completely through in just a few seconds. Still other soils may keep the water from getting in at all. None of these soil types is better than the other - they are simply good for different reasons. Which soil property would you look for if you wanted to plant a garden? Build a driveway or a playground? What happens if the soil is full of water and a heavy rain falls on it? How can you change the way your soil holds water? What happens to the soil when organic matter is added, when plants are growing on top of it, when it is compacted, or when it is plowed?

Preparation

- Bring in samples of different types of soil from school or from home.
- Remove the labels and lids and cut off the bottoms of the clear plastic 2 L bottles.
- Place a circle of screen inside the bottle so that it covers the cap opening.
- Pour 3-4 cm of sand onto the screen. The sand will keep the screen from becoming clogged.
- Place the bottle, mesh side down, on a beaker or clear container.
- Pour 1.2 L of soil into the bottle over the sand.
- Copy the Work Sheets for each student

Figure SOIL-L-1



What To Do and How To Do It

Class Investigation

1. Choose a soil (a sandy soil works best) to use for demonstration and place 1.2 L of the soil into the 2 liter bottle.
2. Have students look closely at the soil. What do students notice: Color? Plant matter? Does it feel light or heavy? Granular (like cookie crumbs) or blocky (chunky)? Record their observations about the soil on the board.
3. Pour 300 mL of water into a 500 mL beaker or other clear container for pouring. Have students notice the clarity of the water.
4. Use a black marker to draw a line showing the height of the water in the pouring container. Have students count the cm lines to reach the top of the water. Record this number on the board.
5. Ask the students "*What will happen if you pour the water onto this soil*"? Ask students to explain why they think the soil and water will behave this way when water is poured onto it. Some possible questions to ask are:

- *Will the water run out through the bottom of the bottle?*

- *Will all of it run out? How much will run out?* Make a mark on the pouring container with a red pen to show how much of the water students think will flow out.
- How fast will the water pass through the soil? *Older students may time with a clock or stopwatch. Younger students can time by marking the minutes off on a timer (like in the Work Sheets) as the teacher times.*
- What will the water look like when it comes out the bottom? Clear? Murky? Very Dirty?

6. Record the class 'hypotheses' on the board.
7. Pour the water onto the soil and begin timing. Ask students to describe what is happening as you pour the water:

- Is all the water staying on top?
- Where is it going?
- Do you see air bubbles at the top of the water?
- Does the water coming out of the soil look the same as the water going in?
- Does the soil look different where the water has gone?

8. Record the class observations on the board. Also record how long it takes for the water to pass through the soil.
9. Ask students to compare their hypotheses and the results of the experiment.
10. Once the water has stopped dripping from the bottom of the bottle, remove the soil bottle and hold up the beaker of water which has passed through the soil. Ask students:

- Is this the same amount of water that we started with? How can we tell if it is the same amount?
- *Pour the water back into the original container. Compare the amount left with the black line on the container.* How much water is missing? How could we measure how much is missing?
- *Compare the water level to the red line on the container.* Is there more or less water left than we thought there would be? How could we measure the difference? Why did you think there would be more or less?
- What happened to the water that is missing?
- Is the water more or less clear than before it passed through the soil? Why?

11. Keep the water that was poured through for comparison.
12. Using the bottle of saturated soil, ask students what will happen if you pour another 300 mL of water into the soil. Record the class hypotheses on the board.

- Will the same amount, more, or less water stay in the soil this time?
- Will it move through faster or slower or at the same speed?
- How clear will the water be? The same, more clear, or less clear than before?

13. Pour the water through the saturated soil, keep the time, observe the results, and compare with the hypotheses. Ask students:

- *Did the water flow through faster than before? How do you know?* Compare the two times.
- *Did more of it flow through than before? How can we find out?* Compare the amounts in the beakers.
- *Is the water as clear as the first time?* Compare the color of the water in the two beakers.

Group Investigation

Experimenting with different soils

Discussion

1. Review the properties of the various soil samples that were brought in.
2. Ask students if they think water would pass through all of the types of soils in the same amount of time and if all the soils would hold the same amount of water.
3. Discuss which soils they think might be different.
4. Provide each group of students with one of the various soils.

Observation and Hypotheses

1. Give each student the Look and Guess Work Sheet.
2. Ask the students to fill in the **Color** of their soil (in words or with a crayon).
3. Ask the students to circle the **Structure** which looks most like their soil.
4. Ask students to look for leaves or **Organic matter** in their soil. Circle YES if they find organic matter. Circle NO if they do not.
5. **Time** Remind students of the observations which they made during the demonstration. Ask students to guess the amount of time it will take water to flow through their soil. Circle the time on the timer, then write the number in the blank.
6. **Amount** Ask students to draw a RED line on the container showing the amount of water they think will flow through their soil.
7. **Clarity** Ask students to put an X on the container which will look most like their water after it flows through their soil.

Experiment and Report

1. Explain that when you say 'GO' everyone will pour their water in together.
2. You will begin to time when the water is poured.
3. Have students fill in the Experiment and Report Work Sheet for their soil.

Have each group report on the results of their experiment to the class. Reports should include **Questions, Hypotheses, Observations and Conclusions** about the experiment. Students can use their Work Sheets to prepare their reports.

Further Investigations

1. Using distilled water, have students measure the pH of the water.
2. Predict whether the pH will be different after the water passes through the soil.
3. Pour the water through, then test the pH again.
4. Have students draw conclusions about the affect of soil on water pH.

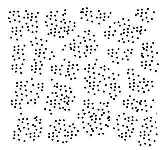
Note: 1. Use this procedure to experiment with conductivity by measuring the conductivity of distilled water before passing it through the soil, then using saltwater and passing it through the soil. 2. Experiment with filtering by using very murky water and passing it through clean sand.

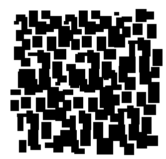
Soil Investigation

Just Passing Through Beginners Work Sheet

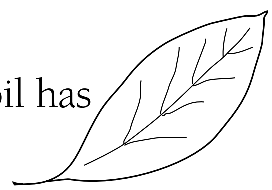
Look and Guess

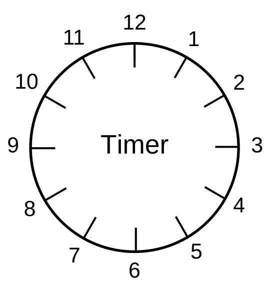
My soil is ______________ color

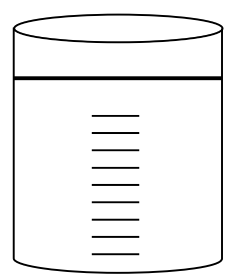




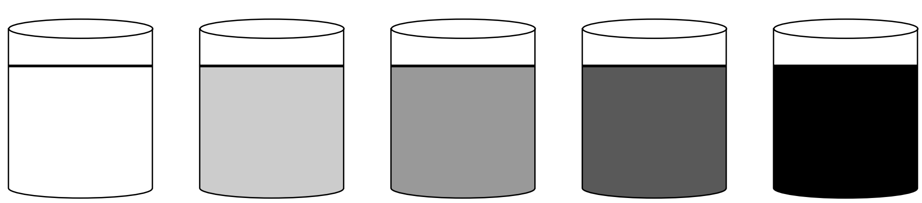
My soil looks granular blocky

My soil has  leaves. YES NO

Time _________ 

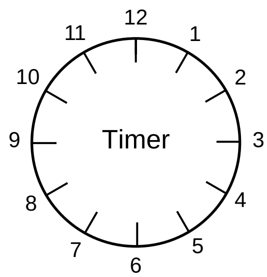
How much water will come out? Make your line RED. 

What will the water look like? (CIRCLE)

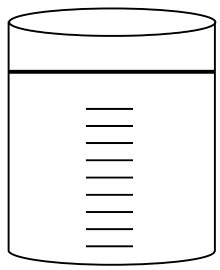


Experiment and Report

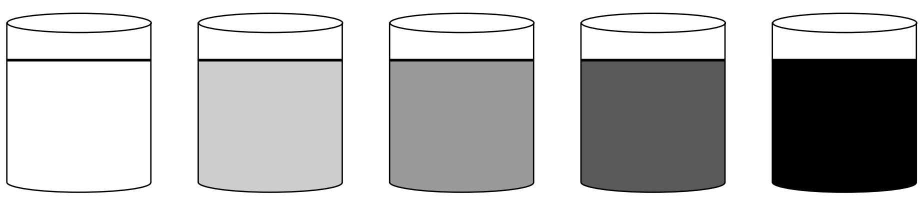
Time ________



How much water came out?



What did the water look like?



My Report

____

____

____

____

Just Passing Through

Purpose

To develop an understanding of some of the relationships between soils of different types and water

Overview

Students will time the flow of water through soils with different properties and measure the amount of water held in these soils. They will also experiment with the filtering ability of soils by testing the pH of the water before and after it passes through the soil and observing changes to the clarity of the water and to the characteristics of the soil.

Time

One class period for initial activity
2-3 class periods for Further Investigations

Level

All

Key Concepts

- Water flows through soil.
- Soil holds water.
- Water affects soil properties.
- Soil properties (particle size distribution or texture, structure, organic matter, layering, etc.) affect flow rate, water holding capacity, nutrient filtering ability, etc.

Skills

- *Asking* questions
- *Developing* hypotheses
- *Testing* hypotheses
- *Observing* results
- *Analyzing* results
- *Drawing* conclusions
- *Measuring* volume
- *Timing*
- *Measuring* pH
- *Measuring* NPK (Nitrogen, Phosphorous, Potassium)

Materials and Tools

(for each team of 3 - 4 students)

- 2 - 3 clear 2-liter bottles*
- 4 - 6 500-mL beakers* or similar size clear containers to pour and catch water for the demonstration, more as needed for the class activity. The number of beakers will be dependent on the number of student groups.
- Soils samples (Bring in 1.2 L samples of different types of soil from around the school or from home. Possibilities include top soil (A horizons), subsoils (B horizons), potting soil, sand, soils that are compacted, soils with grass growing on top, soils with clearly different textures).
- Fine window screen or other fine mesh that does not absorb or react with water (1 mm or less mesh size)
- Strong tape
- Scissors
- Water
- Laboratory ring stands with rings, if available (enough to hold the number of plastic bottles to be used). Another approach is to rest the bottles in the top of the beaker (this method does not use the laboratory ring stands). With the soil weight, the bottles will be relatively stable setting in the beakers.
- pH paper, pen, or meter
- Work Sheet
- GLOBE Science Notebooks

For Further Investigations:

- Distilled water, salt, vinegar, baking soda
- Plastic wrap to cover bottles
- Conductivity meter
- NPK kit
- Growing sod or mulch
- Alkalinity kit

*You can use 1-liter bottles and either 400 or 250 mL beakers. The size of the beakers will be dependent on the diameter of the bottles. The bottle with the screen should not descend too deep into the beaker so that it impacts the reading of the volume of water. The smaller size bottle has the advantage of requiring less soil. Regardless of which size bottle is used, it is important that the amount of soil, water and size of the beakers and bottles used in comparative experiments are the same.

Preparation

Discuss with students some of the general characteristics of soils or do *Soil in My Backyard* or the *Soil Characterization Protocols*.

Prerequisites

None

Background

What happens to water when it passes through soil depends on many things such as the size of the soil particles (texture and particle size distribution), how the particles are arranged (structure), how tightly they are packed (bulk density), and the attraction between the soil particles and the water. Some types of soil let water flow in quickly (infiltrate), then hold the water inside the soil (water holding capacity). This might give plants a better chance of using some of that water. Other types of soil may let the water go completely through in just a few seconds. Still other soils may keep the water from getting in at all. None of these soil types is better than the other - they are simply good for different reasons. Which soil property would you look for if you wanted to plant a garden? Build a driveway or a playground? What happens if the soil is full of water and a heavy rain falls on it? How can you change the way your soil holds water? What happens to the soil when organic matter is added, when plants are growing on top of it, when it is compacted, or when it is plowed?

Water in soil is also a key to the transfer of nutrients from the soil to growing plants. Most plants do not eat solid food (although a few do digest insects!) Instead, they take in water through their roots and use the nutrients the water has obtained from the soil. How nutritious is soil? That depends on how the soil was formed, what it was formed from, and how it has been managed. Farmers and gardeners often add *nutrient*s or fertilizer to soil so that it will be better for their plants.

Preparation

- Bring in samples of different types of soil from school or from home.
- Collect a number of clear plastic 2 liter bottles with straight sides. Remove the label and lid and cut off the bottom and the top so that the end will fit into a 500 mL beaker or other clear container. Note that some of the curve of the top part of the bottle should be kept so that the bottle will fit into the beaker.
- Cut a circle of a fine mesh window screen or nylon net about 3 cm larger than the opening made in the top of the bottle. Using strong tape, secure the mesh circle around the end of the bottle where the top was cut off.

Place the bottle, mesh side down, on a beaker or set it in a ring stand and place a catchment beaker under it.

What To Do and How To Do It

Class Investigation

1. Observe the properties of the soil samples that will be used. Use your GLOBE Science Notebooks to record information about the soil samples which you observe. Also record where each sample was found and the depth at which it was found. If you have done the soil characterization

protocols, you can also record the moisture status, structure, color, consistence, texture, and presence of rocks, roots and carbonates.

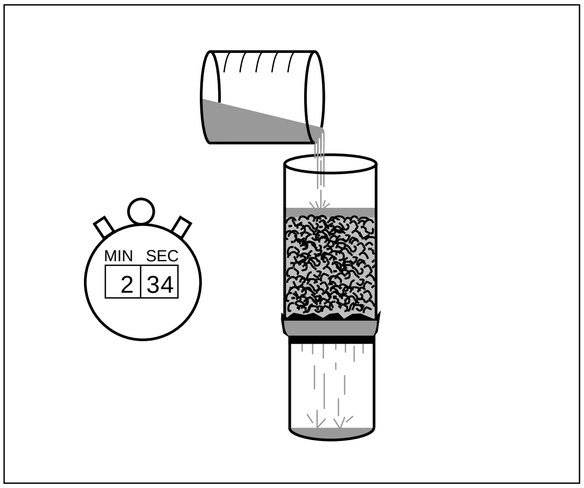
2. Choose one soil (a sandy loam works best) to use as a demonstration and place 1.2 L of the soil in one of the 2 liter bottles.
3. Pour 300 mL of water into 500 mL beaker or other clear container for pouring. Measure the pH of the water. Also, notice the clarity of the water.
4. Ask the students "*What will happen if you pour the water onto this soil*"? Ask students to explain why they think the soil will behave this way when water is poured onto it. Some possible questions to ask are:
   - *How much water will flow out the bottom of the container?*
   - *How fast will the water pass through the soil?*
   - *Will the pH of the water change, and if so, how?*
   - *What will the water look like when it comes out the bottom?*
5. Record the class hypotheses on the board and ask the students to record the hypotheses in their GLOBE Science Notebooks.
6. Pour the water onto the soil and begin timing. Ask students to describe what is happening as you pour the water:
   - Is all the water staying on top?
   - Where is it going?
   - Do you see air bubbles at the top of the water?
   - Does the water coming out of the soil look the same as the water going in?
   - What is happening to the soil structure, especially at the soil surface?
7. Record the class observations on the board and have the students record the information in their GLOBE Science Notebooks. Also record how long it takes for the water to pass through the soil.
8. Ask students to compare their hypotheses and the results of the experiment.
9. Have students record their own conclusions in their GLOBE Science Notebooks about how the water and soil interacted.
10. Once the water has stopped dripping from the bottom of the bottle, measure the amount of water that moved out of the soil into the beaker. Ask students:
    - What happened to the water that is missing?
11. Notice the clarity of the water.
    - Is it more or less clear than before it passed through the soil?
12. Test the pH of the water in the beaker that has flowed through the soil, record the results, and compare the results with the pH of the water that was poured into the soil. Compare with the student hypotheses.
    - Did the pH change?
    - If so, what might have caused this change?
13. Using the bottle of saturated soil, ask students what will happen if you pour another 300 mL of water into the soil. Record the class hypotheses on the board.
    - How much water will stay in the soil?
    - How fast will it move through?
    - Will the pH change?
    - How clear will the water be?
14. Pour the water back through the soil, observe the results, and compare with the hypotheses.
15. Have students record their questions, hypotheses, observations and conclusions in their GLOBE Science Notebooks.

Group Investigations

Experimenting with different soils

1. Review the properties of the various soil samples that were brought in.
2. Ask students if they think water would pass through all of the types of soils in the same amount of time and if all the soils would hold the same amount of water.
3. Discuss which soils they think might be different and how.

Figure SOIL-L-2



4. Have each group of students select one of the various soils.
5. Have each group repeat steps 2 - 15 above on their own soil. Instead of writing hypotheses and observations on the board, the students will record the experiment in their GLOBE Science Notebooks.
6. Have each group report on the results of their experiment to the class. Reports should include questions, hypotheses, and observations regarding the following variables, as well as their conclusions about the variables and how they affected the results of their experiment.
   - soil characteristics
   - original water pH and clarity
   - amount of time for the water to pass through the soil
   - the amount of water which passed through the soil
   - changes in water pH and clarity
   - results of the saturation test.

Note: The information collected in the students' GLOBE Science Notebooks will be used to prepare their papers and reports.

7. Review all results with the class. Have the class determine the soil characteristics, such as different size of particles, space between the particles, organic material which may hold water, etc. associated with the fastest and slowest infiltration, retention of water in the soil, and changes in pH and clarity.
8. Based on the comparison of their hypotheses with the experimental results, record conclusions about how the water and soil interact and how diverse soils behave differently in their GLOBE Science Notebooks.
9. Ask the students to explore how what they have learned from their experiment may be used in real life circumstances to understand what might occur in their local watershed and land use questions in their community. They might explore questions such as:
   - *What might happen if the soil in an area is tightly compacted and there is an extended heavy rain?*

Further Investigations

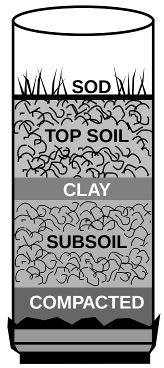
1. Challenge students to come up with strategies for building a soil column in a 2 liter clear, plastic bottle which will SLOW or SPEED UP the rate of water flow through a soil.

   Brainstorm ideas for accomplishing the task. Hint: soil may be sifted and the particle sizes layered. Students may also add clay, sand or mulch. Soils may be compacted. Have students record their method and measure and record the 'soil recipe' they use. Hint: The rate of flow may be very slow for loams or clayey soils. Teachers may want to have students build their soil column one day, then have a student come in before class the next day and start the water flow.

   Record the results for the rates of water flow. Which strategies worked best? Ask students to determine whether the same strategies work for moving water through the soil slowly and for holding water in the soil.

2. Build a soil column similar to the soil profile at one of your soil characterization sample sites (use the samples for each of the horizons in the same order they are found in the profile). Observe how the water-soil interaction occurs in a simulated profile.

Figure SOIL-L-3: Experimental Soil Column



More Advanced

Based on the observations and results of their experimentation, have students design experiments to test other hypotheses they may have developed. Some possible ideas include:

1. Have students hypothesize about how soil can affect other aspects of the chemistry of water. Take a reading of NPK using the Soil NPK kit with the soil alone, and with a water sample. Repeat the water measurement after it has passed through the soil.
2. Have students experiment with adding salt to the water and testing the conductivity or salinity of the water before and after it goes through the soil.
3. Add vinegar or baking soda to the water and test the pH and alkalinity before and after water is added to the soil.
4. Ask the students to hypothesize about the effect of evaporation on the amount of water the soil will hold. What are the factors that control evaporation? Use some soil of the same type in two bottles and saturate both with water. Leave one bottle open on top and cover the other bottle securely with plastic wrap or other cover. Place both in a sunny window. The weight of the soil in each of the bottles will be a function of how much water it holds over time. Students can graph the difference in weight over time for the covered and uncovered bottles.
5. Place a mulch or growing sod over the soil in the bottle. How does this affect the rate at which water infiltrates the soil? How does it affect the clarity of the water that comes out the bottom? How is this related to erosion in the real world?
6. Ask students what changes may occur if the soil remains saturated with water over long periods of time. Place a soil sample in a bottle which has not had the bottom removed, then saturate it. Can they detect changes in structure, color, smell? How long does it take for changes to take place?

Have students examine soil moisture data for five GLOBE sites which have approximately the same amount of precipitation over a six month period. Graph the monthly soil moisture for each site. How do the graphs differ? What other GLOBE data can students find that might explain the variation?

Student Assessment

Students should know the scientific method and how to use it to set up an experiment as well as understand the scientific content relating to soil moisture. They should also be able to demonstrate higher order thinking skills such as drawing conclusions from experimental observations and they should be able to justify their conclusions with evidence. These can be assessed by using a portfolio assessment of their GLOBE Science Notebooks, class participation in discussions and the contribution of questions, hypotheses, observations and conclusions. The quality of their presentations are another mechanism for assessing their progress. It is also a good idea to have the students prepare a written report or a paper on their experiment. The experimental work should be done in groups as should the presentations and the reports so that their ability to work cooperatively in groups can also be assessed.

Note: This activity works nicely when done in conjunction with the soil moisture protocol. The activity can begin in the classroom before going out to set up the sampling strategy or take a soil moisture measurement. Additional observations and recording of flow rate, volume of water, pH, water clarity, etc. can be taken when returning to the classroom. (For some soils, it may take some time before all the water flows through the soil columns.) The activity also places both the soil moisture and soil characterization protocols in a conceptual context for the students. They will understand why the information and data they collect are important for developing hypotheses, designing experiments to test the hypotheses, interpreting observations, and making conclusions. They will also develop an understanding of the potential research significance of the soil moisture and characterization data.

From Mud Pies to Bricks

Purpose

To introduce the different particle sizes of soils and the properties which each contributes to the soil character

Overview

Students will sift soil to remove organic materials and pebbles. They will then sift the soil with smaller meshed sieves to separate clay and sand. Students will make mud pies by adding water to the various soil components, letting them dry and observing the pie's characteristics. Finally, students will be challenged to create the perfect mud pie or building brick using combinations of soil components.

Time

One class period to sift soils and make mud pies

Overnight to dry

One class period to experiment with creating bricks

Overnight to dry

Level

All

Key Concepts

Soil is composed of a variety of materials.

The size of soil particles helps determine the soil characteristics.

Soil is important as a building material.

Skills

Sifting soil samples

Observing differences in particles

Measuring or *weighing* soil

Designing experiments

Testing results

Materials and Tools

1 liter soil (loam) for each student group

Several sizes of mesh screen or sieves for sifting

Straw (dried grass clippings)

Additional powdered clay and sand

Old ice cube trays (for brick molds)

Small plastic lids or plates (for pies)

Plastic table cloth

Prerequisites

None

Background

Soil is made up of many different size grains of broken-down rock (sand, silt and clay). How much water a soil will hold, how easily water passes through the soil, and what happens to the soil as it dries depends on the combination of these materials in your particular soil. Soil with too much clay may crack as it dries - you have probably seen pictures of ground with huge cracks or observed the cracking at the top of a mud puddle when larger, heavier particles have settled to the bottom. Soil with too much sand may not hold together well or be strong enough as a building material.

Soil has been used as a building material for thousands of years, and is still one of our most important building materials. In dry regions houses built of adobe bricks last hundreds of years. Concrete and bricks are common everywhere. Whether you are making concrete or adobe blocks, it is important to understand the importance of having the right elements in your soil mix.

What to Do and How to Do It

Observation

1. Ask students to examine the soil carefully using their eyes, hands, and a magnifying glass.

2. Make a list of the things students observe about the soil. For example: *different size, shape, and color of grains, other soil materials such as sticks or leaves, 'dustiness', weight, etc.*
3. Ask students if they think the soil would be different if all of the particles were alike or if some parts were missing. How would it be different?
4. Starting with the largest mesh sieves, sift the soil.
5. Place what does not go through the sieve in one pile - these are the largest particles.
6. Ask students to examine the 2 piles. How are they alike and different? Can they think of reasons why different size particles would be good for different things?
7. Take the soil that passed through the sieve and sift it through the next smaller mesh.
8. Keep what did not go through the sieve separate, and continue sifting through smaller mesh screens. Students will now have several piles of soil separated by the size of the particles.
9. Ask students to identify words that describe the different piles of soil they now have. Identify the concept of particle size: sand, silt and clay. Words might include: *powdery, rough, smooth, dusty, etc.*

Experimenting

1. Discuss with students the importance of soil as a building material. Ask students to identify things that are built with soil. Example: *concrete sidewalks, brick buildings*
2. Have students describe how they would make a brick using the soil they have.
3. Ask students to describe the characteristics of a good mud pie or brick. For example: *hardness, cracking, resistance to breaking or water, etc.*
4. Ask students to guess which pile of soil would make the best mud pie or brick. Why did they choose the pile of soil that they did? What will happen to each pile when water is added to it?
5. Have students make mud pies or bricks from the soil in each pile by adding water then molding by hand or putting into a mold like an old ice cube tray.
6. Dry completely in the sun or in a warm place.
7. Ask students to test the mud pies or bricks that they made for breaking, cracking, smoothness, etc.. List what is good or bad about each one.

More Challenging

1. Challenge students to create the perfect mud pie or brick by combining different amounts of the soil particles they sifted out. Additional sand, clay or organic material may be provided, especially if your original soil did not contain very much of one of these elements. Have students measure or weigh the different ingredients and write a 'recipe' so that they can compare with other students or recreate their creation.
2. Older students can figure the percent weight of each soil component in their recipe.

Further Investigations

1. What happens when the dried bricks get wet? Research how adobe houses are protected from rain.
2. Examine a piece of broken brick. What soil elements can you identify? Why are bricks water resistant?

Assessment

Have students observe soils around their school or at their biology site. Ask how they can determine areas which have more clay or more sand.

Recipe Card	amount
Ingredients:	
clay (smallest size particles)	
silt (medium size particles)	
sand (large size particles)	
other	
other	

Soil and My Backyard

Purpose

To explore soil and soil properties

Overview

Students will discover the variability of soils, derive relationships among soils and the soil forming factors, and link the GLOBE Soil Investigation to the students' local environment. Students use soil samples from their homes to identify properties that characterize their soils. They compare and contrast their soils to those of their classmates. As a class, students describe relationships between the properties of their soils and how and where they were sampled. Older students construct a soil classification schema.

Time

One class period to observe soil properties and one or two periods for discussion

If soils are to be dried and changes observed, an additional class period will be needed.

Level

All

Key Concepts

Soils vary within a small local area

Soil properties are related to the soil forming factors.

Soil can be classified according to its properties.

Skills

Sampling of soil

Classifying soil

Materials and Tools

Newspaper

1 liter plastic bags

Local map (topographic or road map which encompasses the school district)

Magnifying glass.

Preparation

On the day of the activity, prepare an area in the room for observing the soils. For example, cover lab tables with newspaper. If students will be drying their samples, you will need to identify a place where soils can be left undisturbed for several days. See the instructions for drying soils in The Soil Protocols – *How to Perform Your Soil Measurement*.

Prerequisites

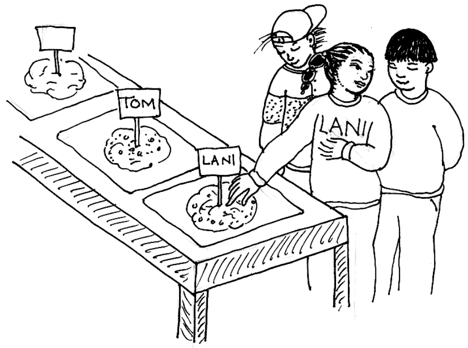
None

Background

Soils vary in their properties depending on where they have been sampled on a landscape and from what depth they were sampled. As your students examine their soils, help them to think about what they are observing by asking: What properties do you notice? Are the soils wet or dry? What colors do you see? Can you identify the components (organic material [both plant and animal], rock fragments, sand, clay, etc.) of your soils? How does the soil smell? How do the soils feel? How do dry soils differ from the original soil samples? Are there differences within a single soil sample? How does your sampling procedure effect what you see? How would you group or classify their soils?

What To Do and How To Do It

Before giving the student the homework assignment of collecting soil samples ask them to hypothesize how many different types of soils the individuals in the class can find in their



neighborhoods. They need to use previous experience or knowledge to answer the question.

Before Class

Have students bring soil samples from home, using 1 liter plastic bags. They should document their collection methods (such as noting the location from which each sample was taken, the depth of the soil, storage methods, etc.). For younger students you may want to establish a class protocol for sample collection – either through a brainstorming activity or by providing one.

During Class

In the classroom, students should spread out their soil samples and examine them closely. Record observations about the soil in their GLOBE Science Notebooks.

Have each student find one person in the class that has a soil similar to their own soil. Record how they determined that the soils were similar.

Have each student find one person in the class that has a soil that is different from their own soil. Record how they determined that the soils were different.

As a class, brainstorm and list on the board the different characteristics the students used to describe their soils. Ask the students to group characteristics that appear to belong together. Use words that describe these similarities, such as same color, same "feel," a number of roots. Have students describe how the observed soil properties relate to the soil forming factors.

Discuss what factors could lead to the different characteristics (five soil forming factors, sampling effects, etc.).

Ask the students to compare their observations with their hypotheses about how many types of soil they are likely to have represented in the class samples.

Ask them to discuss how their knowledge of the soil characteristics changed based on their investigations. What did they learn? Be specific listing such things as soil characteristics, how soil may vary in characteristics within a relatively small area, etc.

Adaptations for Younger and Older Students

Younger students should focus on making observations and comparisons.

Older students can perform more in-depth investigations in teams or as a class by:

Developing a standardized procedure for soil sampling and having your students bring in a second sample collected by following the class procedure. Compare each set of samples.

Developing a scheme to classify soils based on soil properties.

Drying the soil samples for different lengths of time and comparing physical differences between soil in various states of moisture.

Plotting on a local map sample collection sites and the distribution of the various soil classes.

Further Investigations

Find out where there is digging (excavation) going on nearby and visit the site, comparing what you observe there with the soil characteristics described in your backyards.

Remember: Safety is always your first concern.

Select another school in a part of the world known for certain characteristics (e.g. a rainy season, thick vegetation, etc.). Pick a school that has a history of submitting messages and/or data. Write a note to the students via GLOBEMail describing your soil and asking them to describe their soil to you. How do the differences in your climates (for example types of seasonal cycle, temperature ranges, amounts of precipitation, types of land cover) relate to the differences in your soils?

Compare your results with those of the other school and discuss any difference with your GLOBE colleagues at your school and the other school.

Investigate what kinds of soils make the best homes for earthworms or other soil-dwelling creatures.

Develop a scheme for grouping (classifying) soils based on soil properties.

Student Assessment

Give students samples of a mystery soil. Depending on their age, they could:

Describe the soil in their GLOBE Science Notebooks, using as many adjectives as possible and covering as many soil characteristics outlined in the Soil Characterization Information Sheet as can be observed.

Consider the implications of the characteristics for its possible history and location.

A Field View of Soil - Digging Around

Purpose
To understand that variations in the landscape can affect soil properties

Overview
Students will investigate variations in the soils around their school to discover that soil properties like moisture and temperature exhibit considerable variability across a single landscape. They will be able to identify factors such as slope, shade, plants, compaction, which affect the appearance of soils and their ability to hold moisture.

Time
Two class periods: the first for the field trip; the second to discuss findings and causal connections

Level
All

Key Concepts
Soil profiles can be described based on the five soil-forming factors.

Soils within a small geographic area can show considerable variety.

Soil factors also affect soil moisture content and temperature.

Skills
Observing and *describing* soil samples

Collecting data in the field

Identifying relationships between the soil-forming factors and the resulting soils

Materials and Tools
Small shovel or trowel

GLOBE Science Notebooks

Prerequisites
None

Background

Factors Affecting Soil Properties
Every soil is unique on every place on Earth. What makes each soil unique is the way the five soil forming factors work together at any particular place. As you look around your site, notice if the effects of the five soil-forming factors are different on one part of the site than another.

Some properties that you may notice that change from one soil to the other are :

- the color
- the kind and amount of vegetation on the soil surface
- the amount of roots in the soil surface
- the shape of the soil particles when you look at them (called the soil structure)
- the way the soil feels (called the soil texture)
- the amount and size of rocks in the soil
- number of worms or other animals in the soil
- how warm or cool, wet or dry the soil feels. (Wet soil will be sticky and clump together, moist soil will feel wet and cool, and dry soil will feel like it has no water in it.)

Factors Affecting Soil Moisture
Because each soil is unique, each soil will also hold a unique amount of water. The amount of water held in the soil may depend on many things. Among these are the speed at which precipitation (rainfall, snowfall, sleet, etc.) enters (infiltrates) the soil or runs off, the temperature, and the plants. If soil is tightly compacted, as on a well-trodden path, the water will not be able to enter the ground as easily as in less traveled areas. Nature may increase runoff in some areas. For example, in dry climates, "desert pavement" (small rocks laid tightly across the sand like a tile floor) may increase the amount of runoff.

Wind and water may help to form crusts on some soils that prevent the infiltration of water. Slope also increases the speed at which water runs off the land. Rain will quickly disappear on a steep slope, but collect in puddles on the flat ground. The roots of plants help to break up the soil, creating a *porous* medium in which water can pass. Sandy soils usually let water in faster than clay soils.

You might think that there is little variation of temperatures on your site. However, there may be quite a bit of difference from one place to another. Shade makes cooler temperatures. Shade is not found just under trees. It may be cooler in the shade under a rock or on the side of a rock away from the sunlight. The soil may be drier in warm places, and wetter in cool, shady places.

Plants may also affect soil moisture. They may provide shade. They also use water.

What To Do and How To Do It

Begin by Asking:

1. In your part of the world, which side of a slope gets the most sunlight - the north or the south?
2. If you were going to hunt for fishing worms (or other soil dwelling invertebrates), where would you look? Why would you look there? Remember, animals need water, air and nutrients, which are found in various soils. In compacted soils, it is more difficult for animals to survive.
3. Do more types of plants seem to grow on slopes or in valleys? Why?

At the Study Site

1. Divide the class into groups of 3 to 5 students. Each group should have a small shovel or trowel, and their GLOBE Science Notebooks.
2. Have groups look for differences in soil properties at different places in the site by digging up a small amount of soil, looking at it, and feeling it. Have them record what they find in their GLOBE Science Notebooks.

The Five Soil-Forming Factors

Climate: Is one part more shaded or sunnier, cooler or warmer, drier or wetter? How would the temperature and moisture be different in a sandy soil than in a clayey soil? How would this affect the way plants grow?

Topography: Are there different slopes on different parts of the site? Where is it flat on the site? Are there areas that rise up or slope down? What are the different types of positions on the landscape (high spots, middle of the slope, low areas)? Where are the highest places; the lowest?

Plants and animals: How do the types of vegetation change on the site? Can you see evidence of animal life? What kind of insects are present? How is the site used by humans? (such as: is it a park, a field, a lawn, a forest, a plantation, an urban area).

Parent material: From what kind of material was your site formed? Do you see rocks at the surface that can give you an indication? Are these rocks near a stream so that they may have been deposited by water? Could they have been deposited by wind (such as a sand dune), or by gravity down a hill, or by a glacier, or by a volcano? (You may need to do some research to determine the geology of your area).

Time: How long has this site been undisturbed? Is there a lot of organic material on the soil surface? Are there grasses, trees, crops, or other plants that have been growing for a long time without being disturbed? Has there been recent building or construction? If it is a field, has it been recently plowed? Have trees been removed from the site? Has there been a recent flood or other natural disturbance that may have affected the formation of the soil?

Ask them to note types of plants, presence of rocks, roots, and soil animals (such as earthworms), how hard or easy it is to dig, distances to items on the landscape or other things they notice. See the box, the Five Soil-Forming Factors, for guiding questions. Have students list the areas they investigated from the wettest to the driest. Note how the moisture content is affected by the location, the type of plant cover, the position, or other things at the site.

Extensions

1. Have students make a sketch map of soil characteristics on their site.
2. Have students "landscape" their site. If this site was going to become someone's yard, where would you plant things?

Student Assessment

Ask Students:

1. In which parts of the site would you expect soils to be most alike? Consider regions with similar soil forming factors.
2. Where would you locate the soil that is the most typical for your area? Look for large areas within your site which have common characteristics.
3. What things on the landscape affect soil-moisture?
4. What things should you consider when choosing your soil-moisture site in your area?

Soils as Sponges: How Much Water Does Soil Hold?

Purpose

To introduce students to "gravimetric measurements" – calculating the amount of water in a soil sample or other substance by weighing it before and after drying

Overview

Students will weigh a wet sponge, squeeze it to remove water and weigh the dry sponge. This helps students understand that objects can hold water and that the amount can be measured. Students then transfer this concept to soil, weighing wet and dry soil samples, and then apply this wet/dry comparison to other objects, such as leaves and fruit.

Time

Approximately two class periods for the initial sponge and soil activities; then 10-15 minutes per day for about 3 days, as objects dry

Level

Intermediate and advanced

Key Concepts

Different objects can hold different amounts of water.

When objects dry, they release their water.

Squeezing and evaporation are two ways to remove water.

Soil water content is a measure of the amount of water in a soil sample.

Soil water content varies around the world.

Skills

Measuring the weight of wet and dry objects

Comparing the water-holding capacity of different objects

Observing changes in weight over time as an object dries

Calculating the amount of water in soil samples and other objects

Estimating the moisture levels in a variety of objects

Comparing soil water content around the world with GLOBE visualizations

Materials and Tools

Scale or balance

Several sponges

Paper towels

Graph paper (for intermediate or advanced)

Soil samples

Other objects to dry (such as fruit, leaves, vegetables)

Prerequisites

Knowledge of fractions and decimals

Background

Many objects hold water. For living beings, this water is essential for survival. In the case of soil, this water is essential for the survival of the plants and animals that live or grow in the soil. In fact, soil moisture is one of the best predictors of what will grow in an area. This is why Dr. Washburne and Dr. Levine need soil moisture data in their research.

One way to calculate soil moisture is to make a gravimetric measurement. Gravimetric means to find the weight, or the pull of gravity, upon an object. When calculating soil water content, we want to find the weight of the water contained in the soil. To do this we measure the weight of a soil sample, dry it out, and then measure the weight of the dried soil. The difference in the weights is the amount of water originally in the sample. We then normalize by dividing by the dry sample weight.

For example, you might dig up a handful of soil and find that it weighs 100 grams. After the soil has dried, you weigh it again and find that it only weighs 90 grams. Ten grams of water have evaporated from the soil, but this must be normalized, to remove sample size bias, by the weight of the dry soil (90 - 30 = 60 g assuming a 30 g can weight). We can calculate the fraction 10/60=0.167. This is a measure of how much water is in the soil (water content). Since we are using a balance, which depends upon gravity, this is called the gravimetric water content.

Soil water content calculations are simple to do, as long as you care for samples properly and measure accurately. When the air is dry, evaporation can happen quite rapidly. Think how fast you dry off after getting out of the pool on a hot, dry day. Soil samples will dry quickly in the air, too, if they are not placed in a sealed container as soon as they are dug up.

Soil moisture is influenced by many environmental factors, such as temperature, precipitation and soil type, as well as topographic features, such as slope and elevation. Soil moisture is especially important for agriculture. Much of the hard work of farming, such as plowing and discing, is done to try to improve the soil-moisture related properties of the soil. Terracing (making ridges in a field) is done in some areas to prevent too much runoff, while fields are rounded in other places to keep the soil from staying too wet. Further, different crops require different amounts of water throughout their growing season. Understanding how the soil moisture changes through the year can help a farmer decide what to plant.

In this activity, students measure the moisture in several objects, before and after drying. They do these experiments in five stages of increasing difficulty:

Stage 1 – Squeezing water from sponges

Students weigh a wet sponge, squeeze it, then weigh the dry sponge and the water that was squeezed from the sponge. Doing this, they see that, in essence: wet sponge = dry sponge + water. Squeezing is a very visible and immediate way to release water.

Stage 2 – Evaporating water fom sponges

Students do the same exercise as above, except that they let the sponge sit for several hours or a day to let the water evaporate. When they weigh the dry sponge, they should get approximately the same weight as in stage 1 (although evaporation may have removed more water than the squeezing did).

Stage 3 – Measuring soil moisture

Now students transfer the concept of evaporative drying to soil by letting soil samples dry for a day or two. They measure the weight before and after to measure the soil moisture. They compare several soil samples to get a sense of a typical range of values.

Stage 4 – Removing water fom other objects

Students transfer this understanding of measuring soil moisture to determine the moisture of other objects, such as fruit or leaves. They experiment with different ways to dry the objects: fans, squeezing, sunlight, salt, etc. They also estimate the wetness values.

Stage 5 – Using GLOBE visualizations for worldwide soil moisture

Students use the GLOBE visualizations on the Worldwide Web to study a map showing soil moisture in other parts of the world. They discuss why there are differences, and conduct further investigations based on student interest in the topic and the visualizations.

At this time, GLOBE lacks sufficient soil moisture data to produce visualizations. As soon as enough data are available, visualizations will be produced and made available over the Web.

What To Do and How To Do It

Preliminary Exercise

If your students do not know how to use the scale or balance, you should teach them how and let them practice weighing objects.

Stage 1 – Squeezing water from sponges

1. Soak a sponge in water. Weigh it and record the wet weight. Ask your students how much they think it will weigh when it is dry. Record the estimates.
2. Squeeze the sponge and weigh it. Record the dry weight. Discuss with students how their estimates compared with the actual value.

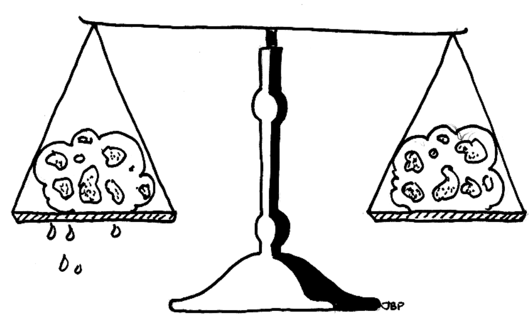
3. Ask your students how much water was in the sponge. See if they can figure out how to calculate this. This amount of water = wet weight of sponge minus the dry weight of sponge. For example, 120 grams of water = 200 gram wet weight minus 80 grams dry weight.
4. Now repeat the measurements with a different sponge. Have your students figure out which sponge can hold the most water.
5. You now have an absolute measure of the water content. Next find the relative measure of water by dividing by the dry sponge weight.
6. To extend this activity, for each sponge you can collect the squeezed out water in a plastic cup, and then weigh the water (make sure you deduct the weight of the cup to get the weight of the water itself). The actual weight of the water should be the same as the calculated weight.
7. In your discussion with your students, make sure they understand the concept of water-holding capacity, and that this differs from one type of sponge to another.

Stage 2 – Evaporating water from sponges

1. Ask your students what will happen if you leave the wet sponge on a tray overnight instead of squeezing it. If your students understand the concept of evaporation, you can discuss that with them. Otherwise, wait until later in this activity to discuss evaporation.
2. Have your students weigh the wet sponge, record the weight, and leave the sponge on a tray, preferably in sunlight. Leave it exposed until the next day.
3. After the sponge has been left out for a day, have your students weigh the dry sponge (it should be dry by now).
4. Ask your students where the water went. Older students who understand evaporation will know the answer. Otherwise explain evaporation to your students.
5. Calculate how much water left the sponge to find out its water-holding capacity. This figure may be different from what they measured when they squeezed the sponge. Ask them why the numbers are close (because both squeezing and evaporating removed most of the water), and then ask them why the numbers are not exactly the same (because evaporation removes more than squeezing, although it takes longer).
6. Ask your students why a high water-holding capacity is important for a sponge, and what other objects might need a high water-holding capacity.

Homework

Explain to your students that they will soon be measuring how much water soil can hold. Ask them to bring in a soil sample from home. They should put the soil sample into a small plastic sandwich bag, then seal the bag to retain its moisture.



Stage 3 — Measuring the moisture of soil

1. Have your students put their soil samples (still in the tightly-sealed plastic bags) on their desks or tables. Ask them how they might measure the wetness of the soil. In their answers, the central concept to look for is to weigh the wet soil, dry it (there are many ways to dry it), and weigh it again, just as they did with the sponge.
2. Have each student or group of students open their sealed baggy, weigh the wet soil, and set it aside to dry. Drying may take a day or two.
3. When the soil is dry (have them touch the soil to feel how dry it is), have your students weigh each soil sample again. Ask them how much water evaporated.

4. Introduce the formula for soil water content. Soil water content =

$$\left(\frac{\text{Wet Weight - Dry Weight}}{\text{Dry Weight - Can Weight}}\right)100$$

This is the formula used in the soil moisture protocol. For example, if the wet weight is 100 grams and the dry weight is 90 grams, and the can weight is 30 grams then the soil water content will be

$$\frac{100\text{ g} - 90\text{ g}}{90\text{ g} - 30\text{ g}} = \frac{10}{60} = .167$$

$$100 \times .167 = 16.7$$

5. Have your students calculate the water content of their soil and compare the values. Correct any errors in their calculations. Discuss the range of values and why they think there is such variety. Have them examine the different soils to help them think about why there is such a range.

Intermediate and Advanced Students

In the above activities, older students can weigh the soil every hour, and then graph the results to see whether water evaporates at a constant rate or the evaporation rate changes, such as slowing the closer the soil gets to being dry, or evaporating more quickly when the sun is shining on it. You might also link the discussion with weather factors, such as how quickly the soil might dry on very dry or humid days.

Homework

Explain to your students that they will be drying other objects. Ask them to bring to class some fruits, vegetables, leaves, rocks or anything else they are interested in experimenting with.

Stage 4 — Removing Water From Other Objects

1. Have your students show and discuss the objects that they brought in to dry. Have them estimate the water content for each object. Record their estimates, either as individual estimates or as class estimates.
2. Have your students weigh each object and record its wet weight.
3. Brainstorm with your students for ways to dry the objects. Previously they squeezed and evaporated water. What other ways are there? How could they speed up or slow down the process? Some ideas are: put the objects in direct sunlight; blow a fan over them; put them on a heater; put them in a microwave or oven; pour salt on them; cover them with a plastic container; point a light on them.
4. Select among the techniques and see the results. The more time you have available, the more your students can experiment.
5. After one or a few days, when the objects are dry, have your students weigh them again. Then have them calculate the wetness of each object. Compare the actual values with their estimates. Which results surprised them?

Stage 5 — Using GLOBE Visualizations for worldwide soil moisture

Intermediate and Advanced Students

Note: Perform this stage once sufficient data have been submitted to GLOBE for visualizations and the visualizations are available on the GLOBE Student Data Server.

This activity is appropriate for intermediate and advanced students who have the requisite map-reading skills and basic understanding of soil moisture issues. Do this activity after your students have begun submitting soil moisture data based on the GLOBE soil protocols.

1. Use the GLOBE Web page to access and display a map showing soil water content around the world based on the most recent student measurements. This is an exciting opportunity for your students because soil moisture data from all over the world have never before been available. Dr. Washburne and Dr. Levine are using the same data for their research.
2. You can display the soil water content data either as values or as contours (with different colored bands corresponding to certain ranges of soil moisture values).

3. Make sure your students make the connection between their own soil water content measurements and the soil water content readings from other schools around the world.
4. There are many domains of investigation for your students. Here are some examples:
   - what is the range of soil water content values around the world?
   - where is it the lowest? the highest?
   - does this vary over time? (examine soil water content maps from other months)
   - what affects the soil water content of the different sites?
   - do soil water content values depend on recent weather conditions?
   - compare readings from a desert, a rain forest and a farming area
   - what areas have about the same level of soil water content as your site?
5. Encourage your students to pursue further investigations using the GLOBE soil water content visualizations.

Student Assessment

Bring a set of soil samples to school. Have your students estimate the soil water content. Have them calculate the soil water content (do not remind them how). Check for reasonableness in their estimates, and watch the process to make sure they do it correctly.

Soil: The Great Decomposer

Purpose

To introduce students to the role that soil, under different environmental conditions, plays in the decomposition of organic materials

Overview

Students will simulate a variety of environmental conditions to determine which conditions facilitate the decomposition of organic material in soil. Variables will include temperature, moisture, and light conditions. Students will use “bottle” experiments to observe changes in the decomposition of vegetable scraps.

Time

One class period to discuss and plan experiment, one class period to set up experiment, part of class period at daily (or every other day) intervals to record results, and one class period 2 weeks later to observe and discuss final results. Additional time may be desired to perform further investigations.

Level

All

Key Concepts

Decomposition in soil depends upon different environmental conditions.

Skills

Conducting an experiment
Observing
Predicting outcomes

Materials and Tools

12 glass jars or beakers or 2-liter plastic bottles (more for additional studies)
Marking pen or labels
Enough dry soil to add 10 cm to each jar. Use the same soil (loam or potting soil) for each jar.
Enough chopped vegetable or fruit scraps (carrots, cucumbers, apples, etc.) to add two to three cm to each jar (use the same fruit or vegetable scrap mixture in all jars). Other sources of organic material include leaves (broken up), grass clippings, flowers, etc. *Do not use animal scraps.*
Graduated cylinder or measuring cup to add specific amount of water to soil
For further studies:
Earthworms (collect from local soil)
Soils with sandy and clayey textures

Preparation

Have the soils, bottles, and vegetable scraps available. Ask students to bring in vegetable scraps on the day of the experiment.

Locate areas in the classroom that will provide variable conditions required for the experiment (warm, sunny site; cool, sunny site; warm, shaded site; cool, shaded site).

Prerequisites

None

Background

Light, temperature and water content largely determine the rate of decomposition in the soil. Soil holds the moisture and heat required for microorganisms to thrive and perform the decomposition process, changing organic materials into soil material called humus.

Soils have different abilities to hold moisture, heat, and to support organisms. If the soil is too wet, too dry, or too cold, decomposition will be slow. Energy from the sun will warm the soil and also promote evaporation, which will affect the moisture content in the soil. Students will be asked to investigate what conditions contribute to rapid decomposition of organic material in soil.

What To Do and How To Do It

Set out 12 jars or beakers on table. Label each as follows:

1. Dry, warm, sunny
2. Moist, warm, sunny
3. Wet, warm, sunny
4. Dry, warm, shady
5. Moist, warm, shady
6. Wet, warm, shady
7. Dry, cool, sunny
8. Moist, cool, sunny
9. Wet, cool, sunny
10. Dry, cool, shady
11. Moist, cool, shady
12. Wet, cool, shady

Add equal amounts of soil (about 10 cm) to each jar.

Add equal amounts (about 2-3 cm) of vegetable material to each jar and evenly mix the soil and vegetable material. Use the same type of vegetable material in all jars.

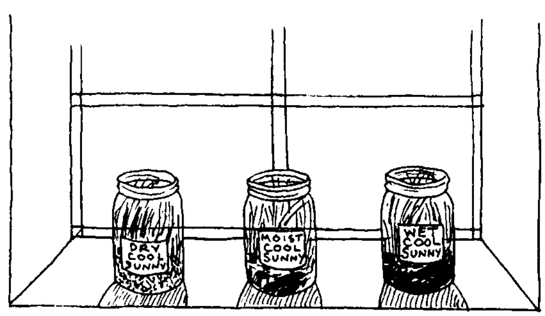
In each of the 4 jars marked "wet," saturate the mixture with water (allow water to cover the surface of the soil).

In each of the 4 jars marked "moist," moisten the mixture with water.

Leave the mixture to dry in the 4 jars marked "dry."

Place one wet, one moist and one dry jar in a warm place that is shaded (as marked).

Place one wet, one moist and one dry jar in a warm place that also gets sun for part of the day (as marked).



Place one wet, one moist and one dry jar in a shaded, cool place.

Place one wet, one moist and one dry jar in a cool place that also gets sun for part of the day (as marked).

Cover the jars but poke small holes in the top for air to circulate.

Every other day, saturate soils in jars that are marked "wet," and moisten soils in jars marked "moist." At this time, stir the soil/vegetation mixture in each jar.

For a period of two weeks, observe the jars daily (or every other day) and record observations. Note changes in water content and the condition of organic matter.

Discuss with the class how light, temperature, and water content affected the amount of organic material left in the soil after 2 weeks. Which jars (conditions) show the most decomposition? Which jars show the least decomposition? Can you rank the jars from the least to most decomposition after 2 weeks?

Once students have discussed their observations, have them design their own optimal decomposer using any combination of the variables in the investigation. Have them justify their choice of conditions and predict how each factor will contribute to decomposition.

Adaptations for Younger and Older Students

For Younger Students

Reduce the number of jars to either:

1. moist, wet, and dry (same temperature and light conditions), or
2. moist, warm and moist, cool (same light conditions).

Talk about which climates across the globe would have these conditions, and compare them to the climate in your local area.

For Older Students

Discuss and relate how decomposition of organic material varies across the globe. What are the sources of organic material in different areas? How does climate affect how fast the organic material will become humus? Have them speculate on what climate conditions will promote the decomposition of organic material and what will inhibit the decomposition of organic material? How would decomposition in a tropical soil differ from that in a northern forest?

Further Investigations

Using soils with "optimal conditions", place earthworms in one jar and leave a second jar earthworm-free. Observe and record earthworm activity, rate of decomposition, and differences in soil properties after 2 weeks between each jar. You may also want to create a "worm farm" in a glass jar to observe worm behavior, decomposition, and changes in soil over a longer period of time.

Do a similar experiment as above but vary the soil texture. Include jars with sandy soil and clayey soil and observe differences as above.

Ask students to research composting.

Making Sense of the Particle Size Distribution Measurements

Purpose

To understand the theory behind the *Particle Size Distribution Measurements* Protocol and how the data can be used to predict percent sand, silt, and clay

Overview

Using the measurements made in the *Particle Size Distribution Measurements Protocol,* the amount of sand, silt, and clay in grams and in percent will be calculated. Students will also be introduced to the theory behind the settling experiment (Stoke's Law), and instructed on how to use the textural triangle with both the results from their measurements and a sample set of sand, silt, and clay measurements for practice.

Time

One class period

Level

Intermediate and Advanced

Key Concepts

How different particle sizes in the soil are distributed to create a specific texture

Stoke's Law and particle settling

Skills

Reading a conversion table

Using mathematics to correct hydrometer readings for volume and temperature

Calculating the amount of sand, silt and clay in grams and in percent of the sample

Reading information from a textural triangle

Estimating percentages

Materials and Tools

Data from Soil Particle Size Distribution Measurements Data Work Sheet

Copy of the textural triangle for each student

Ruler or straight edge

Preparation

Conduct a discussion of different size particles in soils and their distribution. See the Introduction.

Perform the *Particle Size Distribution Measurements Protocol* to obtain the measurements required for this exercise.

Background

The amount of each size particle (sand, silt, or clay) in the soil is called the particle size distribution. Knowing the particle size distribution of a soil sample helps us understand many soil properties including how much water, heat, and nutrients the soil will hold, how fast water and heat will move through the soil, and what kind of structure and consistence will form. Sand, silt, and clay are the 3 particle sizes of mineral material found in soils. The amount of each of these is called the particle size distribution and the way they feel is called the soil texture.

Sand is the largest sized particle, silt is medium sized, and clay is the smallest. There is disagreement in the scientific community about the exact size ranges of sand and silt. For GLOBE, we will measure sand and silt based on 2 different size definitions:

1. The US Department of Agriculture (USDA) which defines the size of sand as 2.0 mm - 0.05 mm, and the size of silt as 0.05 - 0.002 mm.
2. The International Soil Science Society (ISSS) which defines the size of sand as 2.0 mm - 0.02 mm, and the size of silt as 0.02 - 0.002 mm.

Clays are the smallest particles and are defined (by both organizations) as being smaller than 0.002 mm. Particles greater than 2 mm are called stones or gravels and are not considered to be soil material.

Heavy, large particles settle first, so when a soil sample is stirred or shaken in a 500 mL cylinder, sand particles (according to the USDA definition) settle to the bottom of the cylinder after 2 minutes, while the clay and silt size particles stay in suspension. After 12 minutes, the sand, according to the ISSS definition, has settled, leaving the clay and silt size particles in suspension. After 24 hours, the silt size particles have settled, and only the clay stays in suspension to be recorded by the hydrometer.

To Determine the Amount of Sand, Silt, and Clay in Your Soil Sample

The specific gravity hydrometer is an instrument used to measure the density of water which has materials suspended in it compared with pure water. A hydrometer and temperature reading is made at 2 minutes, 12 minutes, and 24 hours during the *Particle Size Distribution Protocol*. To determine the amount of sand, silt, and clay in your sample, we will take each hydrometer reading and make a temperature correction to it. Next, we will use a conversion table (below) to convert the corrected specific gravity of the water to grams of suspended soil per liter (1000 mL) which includes a correction for the density of the dispersing agent that was added. Once we make that conversion, we need to multiply by the number of liters (0.5 L or 500 mL), in order to determine the number of grams of soil in suspension.

Obtain the data recorded on the Particle Size Distribution Measurements Data Work Sheet, and use the Calculation Work Sheet below to perform the following corrections:

1. Begin with your 2 minute hydrometer reading. From the conversion table below, determine the value of grams of soil/liter. At 2 minutes, this value corresponds to the grams of silt (USDA size) plus clay in suspension. All of the sand (USDA size) has settled to the bottom of the cylinder.
2. Note the temperature values you obtained 2 minutes. For every degree of temperature above 20 °C, add 0.36 grams to the grams of soil you obtained from the table. Subtract 0.36 for every degree below 20 °C.
3. Next, multiply the value for temperature-corrected grams of soil/L by 0.5 L to find out how many grams of soil we have in suspension in the 500 mL cylinders. This answer gives you the grams of silt plus clay in your sample.
4. Repeat procedure 1, 2, and 3 for the 12 minute and 24 hour hydrometer readings using the temperature read at each time period to correct for every degree above or below 20 °C. The 12 minute reading corresponds to the amount of silt (ISSS size) plus clay that is in your sample (the ISSS sand has settled at 12 minutes). The 24 hour reading represents the amount of clay in your sample (all of silt and sand has settled by 24 hours).
5. To find out how many grams of sand (according to the USDA) you have in your sample, subtract the amount of silt plus clay you calculated in step 3 above by the original amount of soil you used in the GLOBE Particle Size Distribution Protocol (25 grams). The percent sand is equal to the grams of sand in the sample divided by 25 grams (the original amount of soil), and multiplied by 100 to get percent.
6. To calculate how many grams and the percent of sand (according to the ISSS), repeat step 5 for the grams of silt plus clay you obtained at 12 minutes.

7. The grams of clay in your sample is the amount of clay determined above from the corrected reading at 24 hours. Dividing the grams of clay by the original weight of the sample used (25 grams) will give the percent of clay in the sample.
8. The amount of silt can be calculated by adding the grams of clay (step 7) and sand (step 5 for USDA or step 6 for ISSS) together, and subtracting that amount from the weight of soil added to the cylinder (25 grams). The percent silt is determined by dividing the grams of silt by 25 grams, or by subtracting the sum of the percent sand plus percent clay from 100 percent.
9. Repeat these calculations for the samples from each horizon in your soil profile. Use the Calculation Work Sheet to help your work. You can compare your results with the final results that will be returned to you after you submit the raw data from your Particle Size Distribution Measurements Data Work Sheet to the GLOBE Student Data Server.
10. You can use the Textural Triangle procedure to determine the texture name of your sample that corresponds with the particle size distribution.

Table SOIL-L-1: Conversion Table (specific Gravity to Grams of Soil/L)

Specific Gravity	Grams Soil/L	Specific Gravity	Grams Soil/L	Specific Gravity	Grams Soil/L
1.0024	0.0	1.0136	18.0	1.0247	36.0
1.0027	0.5	1.0139	18.5	1.0250	36.5
1.0030	1.0	1.0142	19.0	1.0253	37.0
1.0033	1.5	1.0145	19.5	1.0257	37.5
1.0036	2.0	1.0148	20.0	1.0260	38.0
1.0040	2.5	1.0151	20.5	1.0263	38.5
1.0043	3.0	1.0154	21.0	1.0266	39.0
1.0046	3.5	1.0157	21.5	1.0269	39.5
1.0049	4.0	1.0160	22.0	1.0272	40.0
1.0052	4.5	1.0164	22.5	1.0275	40.5
1.0055	5.0	1.0167	23.0	1.0278	41.0
1.0058	5.5	1.0170	23.5	1.0281	41.5
1.0061	6.0	1.0173	24.0	1.0284	42.0
1.0064	6.5	1.0176	24.5	1.0288	42.5
1.0067	7.0	1.0179	25.0	1.0291	43.0
1.0071	7.5	1.0182	25.5	1.0294	43.5
1.0074	8.0	1.0185	26.0	1.0297	44.0
1.0077	8.5	1.0188	26.5	1.0300	44.5
1.0080	9.0	1.0191	27.0	1.0303	45.0
1.0083	9.5	1.0195	27.5	1.0306	45.5
1.0086	10.0	1.0198	28.0	1.0309	46.0
1.0089	10.5	1.0201	28.5	1.0312	46.5
1.0092	11.0	1.0204	29.0	1.0315	47.0
1.0095	11.5	1.0207	29.5	1.0319	47.5
1.0098	12.0	1.0210	30.0	1.0322	48.0
1.0102	12.5	1.0213	30.5	1.0325	48.5
1.0105	13.0	1.0216	31.0	1.0328	49.0
1.0108	13.5	1.0219	31.5	1.0331	49.5
1.0111	14.0	1.0222	32.0	1.0334	50.0
1.0114	14.5	1.0226	32.5	1.0337	50.5
1.0117	15.0	1.0229	33.0	1.0340	51.0
1.0120	15.5	1.0232	33.5	1.0343	51.5
1.0123	16.0	1.0235	34.0	1.0346	52.0
1.0126	16.5	1.0238	34.5	1.0350	52.5
1.0129	17.0	1.0241	35.0	1.0353	53.0
1.0133	17.5	1.0244	35.5	1.0356	53.5
				1.0359	54.0
				1.0362	54.5
				1.0365	55.0

Calculation Work Sheet

A. 2 minute hydrometer reading__________

B. temperature at 2 minutes ____________ °C

C. grams/L of soil (USDA silt + clay) from table____________g/L

D. temperature correction[(0.36 x (B - 20° C)] ________g

E. corrected silt (USDA) and clay in suspension (C+D)_______g

F. grams of soil (USDA silt + clay) in 500 mL (E x 0.5)__________g

G. grams of sand (USDA) (25 g - F)________g

H. percent sand (USDA definition) [(G/25) x 100] ___________%

I. 12 minute hydrometer reading__________

J. temperature at 12 minutes ____________ °C

K. grams/L of soil (ISSS silt + clay) from table____________g/L

L. temperature correction [(0.36 x (J - 20° C)] ________g

M. corrected silt (ISSS) and clay in suspension (K+L)_______g

N. grams of soil (ISSS silt + clay) in 500 mL (M x 0.5)__________g

O. grams of sand (ISSS) (25 g - N)________g

P. percent sand (ISSS definition) [(O/25) x 100]___________%

Q. specific gravity at 24 hours__________

R. temperature at 24 hours ____________ °C

S. grams/L of soil (clay) from table____________g/L

T. temperature correction [(0.36 x (R - 20°C)]________g

U. corrected clay in suspension (S+T)_______g

V. grams of soil (clay) in 500 mL (U x 0.5)__________g

W. percent clay [(V/25) x 100] ___________%

X. grams of silt (USDA) [25 - (G + V)] _________g silt (USDA)

Y. percent silt (USDA) [(X/25) x 100]__________%

Z. grams of silt (ISSS) [25 - (O+V)] _________g silt (ISSS)

AA. percent silt (ISSS) [(Z/25) x 100]__________%

Example

Suppose the following were recorded from the 2 minute, 12 minute and 24 hour hydrometer readings:

	Specific Gravity	Temperature
2 minutes:	1.0125	21.0
12 minutes	1.0106	21.5
24 hours	1.0089	19.5

For each hydrometer reading of specific gravity, convert to grams/liter of soil from the conversion table, and correct for temperature.

For the 2 minute reading

The specific gravity reading is closest to 1.0126, which equals 16.5 grams of silt (USDA) and clay per liter in suspension. This value is then corrected for temperature. Since the temperature reading was 1 degree higher than 20°C, add 0.36 to the 16.5 grams/liter:

$$16.5 + 0.36 = 16.86 \text{ g/L}$$

Next, multiply 16.86 g/L by 0.5 L (which was the volume of water used in the protocol) to change from grams/liter to grams:

16.86 x 0.5 = 8.43 which can be rounded to 8.4 g

This is the amount of silt (USDA) and clay in suspension.

To determine the amount of USDA sand, subtract 8.4 g from the original amount of soil added in the Protocol (25.0 g):

25.0 g - 8.4 g = 16.6 g of sand (USDA)

To calculate the percent of sand in the sample, divide 14.1 g by the original amount of soil added in the Protocol (25.0 g) and multiply by 100 to get percent:

(16.6 g/25.0 g) x 100 = 66.4% sand (USDA)

For the 12 minute reading

The specific gravity reading is closest to 1.0105, which equals 13.0 grams of silt (ISSS) and clay per liter in suspension. This value is then corrected for temperature. Since the temperature reading was 1.5 degrees higher than 20°C, add 0.36 x 1.5 to the 13.0 grams/liter:

$$0.36 \times 1.5 = 0.54$$

$$13.0 + 0.54 = 13.54 \text{ g/L}$$

Next, multiply 13.54 g/L by 0.5 L (which was the volume of water used in the protocol) to change from grams/liter to grams:

13.54 x 0.5 = 6.77 which can be rounded to 6.8 g

This is the amount of silt (ISSS) and clay in suspension.

To determine the amount of ISSS sand, subtract 6.8 g from the original amount of soil added in the Protocol (25.0 g):

25.0g - 6.8g = 18.2 g of sand (ISSS)

To calculate the percent of sand in the sample, divide 18.2 g by the original amount of soil added in the Protocol (25.0 g) and multiply by 100 to get percent:

(18.2 g/25.0 g) x 100 = 72.8% sand (ISSS)

Note: The amount of ISSS sand is greater than the USDA sand because ISSS considers sand to contain more fine particles, which USDA would classify as silt.

For the 24 hour reading

The specific gravity reading was 1.0089, which can be read directly off the chart as 10.5 g/L. This value represents the amount of clay per liter in suspension. The 10.5 g/L is then corrected for temperature. Since the temperature reading was 0.5 degrees lower than 20°C, subtract 0.36 x 0.5 from the 10.5 grams/liter:

$$0.36 \times 0.5 = 0.18$$

$$10.5 - 0.18 = 10.32 \text{ g/L}$$

Next, multiply 10.32 g/L by 0.5 L (which was the volume of water used in the protocol) to change from grams/liter to grams:

10.32 x 0.5 = 5.16 which can be rounded to 5.2 g

5.2g is the amount of clay that was in the original 25 g of soil used in the Protocol.

To calculate the percent of clay in the sample, divide 5.2 g by the original amount of soil added in the Protocol (25.0 g):

(5.2 g/25.0 g) x 100 = 20.8% clay

The amount of silt (USDA) is calculated by adding the grams of sand (USDA) to the grams of clay, and subtracting that sum from the original amount of sample (25 g):

16.6 g (USDA sand) + 5.2 g (clay) = 21.8

25g - 21.8 g = 3.2 g silt (USDA)

which can be converted to percent by dividing by 25:

(3.2/25) x 100 = 12.8% silt (USDA)

The amount of silt (ISSS) is calculated by adding the grams of sand (ISSS) to the grams of clay, and subtracting that sum from the original amount of sample (25 g):

18.2 g (ISSS sand) + 5.2 g (clay) = 23.4 g

25g - 23.4 g = 1.6 g silt (ISSS)

which can be converted to percent by dividing by 25:

(1.6/25) x 100 = 6.4% silt (ISSS)

For this sample, the final result would be:

	%Sand	%Silt	%Clay
USDA:	66.4	12.8	20.8
ISSS:	72.8	6.4	20.8

Using the Textural Triangle to Determine the Textural Class Name

Soil Scientists have created classes which break the distribution of particle sizes (soil textures) into 12 categories. Textural Triangle 3 is one of the tools soil scientists use to visualize and understand the meaning of soil texture names. This textural triangle is a diagram which shows how each of these 12 textures are classified based on the percent of sand, silt, and clay in each. **Note:** these percentages are based on the USDA definition of sand and silt only.

Follow these steps to determine the textural class name of your soil sample:

1. Place a plastic sheet or tracing paper over Textural Triangle 3.
2. Place the edge of a ruler at the point along the base of the triangle that represents the percent of sand in your sample. Position the ruler on the line that slants in the direction that the numbers are facing for percent sand.
3. Place the edge of a second ruler at the point along the right side of the triangle. Position the ruler on the line which slants in the direction that the numbers are facing for percent silt.
4. Place the point of a pencil or water soluble marker at the point where the two rulers meet. Place the top edge of one of the rulers on the mark, and hold the ruler parallel to the horizontal lines. The number on the left should be the percent of clay in the sample. Note that the sum of the percent of sand, silt, and clay should add up to 100.
5. The descriptive name of the soil sample (textural class) is written in the shaded area where the mark is located. If the mark should fall directly on a line between two descriptions, record both names.

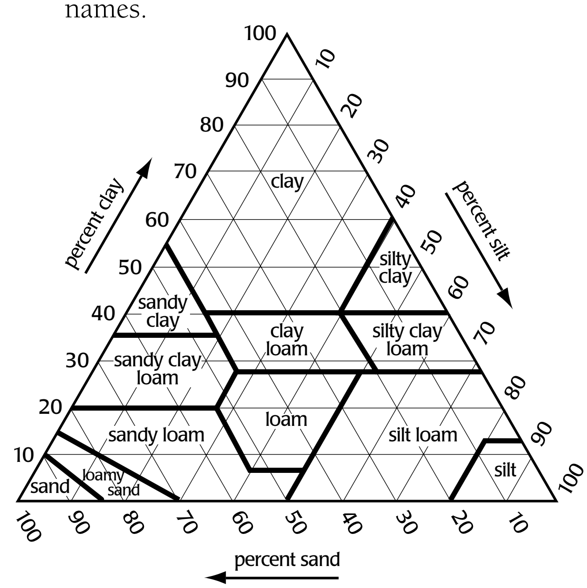


Figure SOIL-L-4: Textural Triangle 3

For the example given above, the textural class of the soil sample would be:

	%Sand	%Silt	%Clay	
USDA:	56.4	12.4	32.2	Sandy Clay Loam

Practice Exercises

Soil Texture Practice Work Sheet

Use the following numbers to determine the soil texture name using the textural triangle. When a number is missing, fill in the blanks. **Note:** the sum of percents and, silt and clay should always add up to 100 percent:

	% Sand	%Silt	%Clay	Texture Name
a.	75	10	15	sandy loam
b.	10	83	7	___
c.	42	___	37	___
d.	___	52	21	___
e.	___	35	50	___
f.	30	___	55	___
g.	37	___	21	___
h.	5	70	___	___
i.	55	___	40	___
j.	___	45	10	___

Answers: b. silt loam; c. 21, clay loam; d. 27, silt loam; e. 15, clay; f. 15, clay; g. 42, loam; h. 25, silt loam; i. 5, sandy clay; j. 45, loam.

Stoke's Law: To Calculate the Settling Time of Soil Particles

In the Soil Particle Size Distribution Protocol, the readings of the hydrometer had to be taken at a very specific time to allow either the sand or silt to settle in the cylinder. In order to determine this time for each size particle, we use an equation derived from Stoke's Law. Stoke's Law describes how fast (the velocity at which) a particle will settle as a function of its diameter and the properties of the liquid in which it is settling. Once this velocity is known, you can calculate the time required for a particle of a certain diameter to settle a given depth in water.

Stoke's Law can be written in the form of the following equation:

$$V = kd^2$$

where:

V = settling velocity (in cm/second)

d = particle diameter in cm (such as 0.2 cm - 0.005 cm for sand, 0.005 cm- 0.0002 cm for silt, and <0.0002 cm for clay)

k = a constant which depends on the liquid in which the particle is settling, particle density, the force of gravity, and the temperature (8.9×10^3 cm $^{-1}$ sec $^{-1}$ for soil in water at 20˚C).

Example

Suppose you wanted to calculate the amount of time it would take a particle of fine sand (0.1 mm) to settle. The distance between the 500 mL mark on you graduated cylinder and the base of the cylinder is about 27 cm.

1. First, convert the diameter of the particle from mm to cm.
   0.1 mm x 1 cm/10 mm = 0.01 cm
2. Using the equation above, plug in values for the diameter of the particle, square it, and multiply by the constant.

$$V = 8900 \times (0.01)^2$$

0.89 cm/second

3. Next, divide the distance between the 500 mL mark and the base on your cylinder by the velocity calculated in step 2.

$$27 \text{ cm}/0.89 \text{ cm second}^{-1} = 30.33 \text{ seconds}$$

Thus, it would take about 30 seconds for fine sand with a diameter of 0.1 mm to settle to the base of the 500 mL cylinder.

Further Investigations

1. Feel the texture of a moist soil sample. Using Textural Triangles 1 and 2 in the *Soil Characterization Field Protocol,* determine the texture. Sand will feel gritty, while silt will feel like powder or flour. Clay will feel sticky and hard to squeeze, and will probably stick to your hand. Look at Textural Triangle 3; find the name of the textural class to which this soil corresponds. Try to estimate how much sand, silt, or clay is in the sample.
2. Practice determining the percent sand, silt, and clay in student samples using the hand "texturing" method along with Textural Triangle 3. Estimates can then be verified with the procedure outlined in the Particle Size Distribution Protocol which will tell them more quantitatively how much of each size particle is in their sample.
3. Once students feel more confident in correctly estimating texture, design a game or competition to see which students can come the closest in their estimation to the actual values determined by the settling method.
4. Develop a set of standard soil texture samples which can be used for students to practice determining soil texture. These standards should include one example of each of the twelve textural classes, with a percent sand, silt, and clay listed that was determined by the settling method.
5. Use the Stoke's Law procedure to calculate the velocity and settling time for a particle with a diameter (in cm) in which students are interested. Be sure to use particle size in cm.

Student Assessment

Verify that students understand the relationship between particle size distribution by testing how well they can determine the textural class of unknown samples by feel. Use practice exercises, such as the ones given above to determine how well they can use the textural triangle.

Acknowledgment:

Adapted from L.J. Johnson. 1979. *Introductory Soil Science: A Study Guide and Laboratory Manual.* MacMillan Pub. Co., Inc., N.Y.

The Data Game

Purpose

To learn how to estimate data results in order to minimize errors in reading or recording data

Overview

Students will participate in a game in which they collect data using various instruments and calculations and then try to fool other data collection teams by exaggerating some of the data numbers. They do this activity first with data about objects in the classroom, then with soil moisture measurements, and then with other GLOBE data.

Time

One class period

Level

All

Key Concepts

Measuring and recording data accurately
Estimates give a “feel” for data quality.
Estimates provide a way to pick out unusual data for further research.

Skills

Measuring and *recording* data
Estimating data values
Evaluating data values based on “reasonableness”

Materials and Tools

For younger students:
Rulers
Measuring tapes
Measuring cups and spoons

For older students:
Instruments for measuring:
a) distance
b) volume
c) circumference
d) weight

Prerequisites

None

Background

Scientists rely on the accuracy of the data submitted by schools. However, even the most careful observer can make a mistake in data collection and recording. It is essential to make sure your data are as accurate as possible. One way to avoid mistakes is to have students critically evaluate any number they write down. Does this number sound reasonable? Is it even possible to have this number? As students become more familiar with the measurements they are taking, they will get a feel for what to expect.

There are two elements necessary for students to judge the reasonableness of data values. First, students have to understand the units of measure: about how far is a meter? How much water is a liter? How much does a liter of water weigh? Second, students need to have a sense of the expected range of data values for the protocol: what are the lowest and highest values one might expect for soil water content? For air temperature?

In this activity, your students will deal with both elements in the form of a game. They will work in groups to collect and record data. Then they change some of the values and have the other students guess which ones are wrong, based on a sense of “reasonableness” of the values.

Using this “reasonableness” criteria is a fundamentally important skill, as it requires students not only to know what values one might expect, but also to take personal responsibility for the accuracy of their data.

It should be stressed that your students may collect accurate data that is unexpected. Estimating what to expect will also help students recognize when their data are unusual and should prompt more investigation.

What To Do and How To Do It

Stage 1 – Estimating data about classroom objects

1. Divide your class into teams of four students. Provide each team with measuring instruments and have the teams collect classroom data. Each team should collect and record 5 to 10 classroom data values.

   Beginning students might:

   count the number of books, tiles, fingers, etc. in the classroom

   measure the length of ten books, the room, around a desk, etc.

   measure the amount of water in a glass, the sink, etc.

   Intermediate students might:

   measure and add distances (the height of a desk and all the desks in the room)

   calculate the height of all text books piled together.

   Advanced students might:

   calculate square meters, cubic centimeters, volume, and weights.
2. Now have each team "disguise" part of their data by exaggerating the numbers. For instance, a cube with a volume of 10 centimeters should be changed to 20 or even 200 centimeters. The less the exaggeration, the greater the challenge for the other students. (You may want to begin with the rule that the exaggerated value is at least double the measured value.)
3. Each team takes turns reporting their data. The other teams must guess whether or not the report is accurate. Each team that is correct gets one point.
4. After all teams have taken turns reporting their data, the team with the most points wins.
5. At the end of the activity, discuss the process of estimating, and the concept of reasonableness. You might want to repeat this activity to see if the students improve.

Stage 2 – Estimating soil water content data

Your students will apply the same concept to soil moisture (you can play the data game with any type of data). You can use soil moisture data that your students have already collected as part of the protocol, or with soil moisture data from the samples students brought from home as part of the activity *How Much Water Does It Hold*?

As described in Stage 1 above, have your students change some of the data values for soil water content, and then have other students guess which values are accurate and which are exaggerated. Score as described above.

Stage 3 – Using data from the GLOBE Student Data Server

1. Have the students access the GLOBE Student Data Server to browse through soil water content data that have been gathered by other GLOBE sites. They should find:

   the range of data for each depth

   the range of data for schools nearby

   the range of data for schools in arid regions or forests or grasslands

   the most common values.
2. Discuss the ranges and common values, and have your students reflect on how this information would help them to do better in the data game.
3. Have your students play the data game again, using global data from the GLOBE Student Data Server.
4. Discuss with your students how this process – reviewing sample data first in order to get a sense of what to expect – is an essential step in estimating values and judging "reasonableness."
5. You can repeat this activity with any of the GLOBE data sets
6. It is also important to point out that abnormal data, often called "outliers," are not necessarily wrong, but certainly need to be looked at closely. Outliers, in fact, are

often the most interesting or important data to investigate further.

7. If any of the values in the GLOBE Student Data Server do not seem correct, then have your students send a GLOBEMail to the school which submitted the data, and ask them if there are reasons for the abnormal value or if they might need to take more care in their next measurement.

Adaptations for Intermediate and Advanced Students

With older students, you can have them graph the data (especially in Stage 3), and then do an analysis of the range, the outliers, the average values, the most common values, and so on. They might also discuss why there are variations from one site to another in the global data set. This in turn relies on a deeper understanding of the science domain, such as soil.

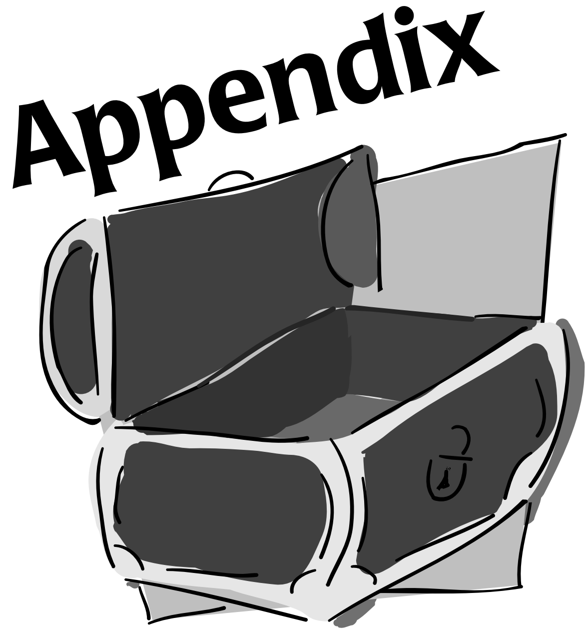
Further Investigations

Whenever your students have problems knowing what are typical values for a protocol, you can have them play the data game. Be sure they review the protocol and sample data sets first so that they'll have a basis for assessing reasonableness.

On a regular basis, review the soil water content and other data submitted by other schools to look for errors or outliers, and communicate with the schools by GLOBEMail to discuss any abnormal values.

Student Assessment

Periodically, when your students do the GLOBE protocols, have one of your students announce the values to the class, including an erroneous value, and see if any other students notice the error. You could reward the error-finding with a GLOBE star or other reward appropriate to the age level. Make sure that the error is corrected before your students submit the data to GLOBE!



Soil Characterization Data Work Sheet

Bulk Density Data Work Sheet-Pit and Near Surface Techniques

Bulk Density Data Work Sheet-Auger Technique

Particle Size Distribution Data Work Sheet

Soil pH Data Work Sheet

Soil Fertility Data Work Sheet

Soil Moisture Study Site Work Sheet

Soil Moisture Data Work Sheet-Star Pattern

Soil Moisture Data Work Sheet-Transect Pattern

Daily Gypsum Block Data Work Sheet

Annual Gypsum Block Calibration Data Work Sheet

Soil Infiltration Data Work Sheet

Soil Temperature Data Work Sheet

Soil Characterization Information Sheet

Textural Triangle 3

Glossary

GLOBE Web Data Entry Sheets

Soil Investigation

Soil Characterization Data Work Sheet

Site Name: ______________________________ *Form Number:* ______________ *Slope:* ______ ° *MUC:* ________

Method (choose one) Pit or Near Surface ________ *Auger* ________ *Existing Exposed Soil Profile* ______

Other Site Characteristics: ____

HORIZON (letter or number)	TOP DEPTH (cm)	BOTTOM DEPTH (cm)	MOISTURE (wet, moist, dry)	STRUCTURE (type)	MAIN COLOR (code from color book)	SECOND COLOR (code from color book)	CONSISTENCE (loose, friable, firm, extremely firm)	TEXTURE (name)	ROCKS (none, few, many)	ROOTS (none, few, many)	CARBONATES (none, slight, strong)

NOTES:

Soil Investigation

Bulk Density Data Work Sheet - Pit and Near Surface Techniques

Date of Sample Collection: __________ Site: __________________________

Horizon Number: __________________ Horizon Depth: Top ________ cm

Bottom ________ cm

Sample Number 1

A. Container volume: __________ mL

B. Container weight: __________ g

C. Wet weight of sample: __________ g

D. Dry weight of sample: __________ g

E. Dry soil weight (D-B): __________ g

F. Weight of rocks: __________ g

G. Volume of water without rocks: __________ mL

H. Volume of water and rocks: __________ mL

I. Volume of rocks (H-G): __________ mL

J. Bulk density [(E-F)/(A-I)]: __________ g/mL (cm^3)

Sample Number 2

A. Container volume: __________ mL

B. Container weight: __________ g

C. Wet weight of sample: __________ g

D. Dry weight of sample: __________ g

E. Dry soil weight (D-B): __________ g

F. Weight of rocks: __________ g

G. Volume of water without rocks: __________ mL

H. Volume of water and rocks: __________ mL

I. Volume of rocks (H-G): __________ mL

J. Bulk density [(E-F)/(A-I)]: __________ g/mL (cm^3)

Sample Number 3

A. Container volume: __________ mL

B. Container weight: __________ g

C. Wet weight of sample: __________ g

D. Dry weight of sample: __________ g

E. Dry soil weight (D-B): __________ g

F. Weight of rocks: __________ g

G. Volume of water without rocks: __________ mL

H. Volume of water and rocks: __________ mL

I. Volume of rocks (H-G): __________ mL

J. Bulk density [(E-F)/(A-I)]: __________ g/mL (cm^3)

Soil Investigation

Bulk Density Data Work Sheet - Auger Technique

Date of Sample Collection: ___________ Site: ______________________________

Horizon Number: ____________________ Horizon Depth: Top _________ cm

Bottom _________ cm

Sample Number 1

A. Sample Depth: Top ___________ cm

B. Sample Depth: Bottom ___________ cm

C. Hole diameter: ___________ cm

D. Hole volume π x $(C/2)^2$ x (B-A) : ________ cm^3

E. Container weight: ___________ g

F. Wet weight of sample: ___________ g

G. Dry weight of sample: ___________ g

H. Dry soil weight (G-E): ___________ g

I. Weight of rocks: ___________ g

J. Volume of water without rocks: _________ mL

K. Volume of water and rocks: _________ mL

L. Volume of rocks (K-J): ___________ mL (cm^3)

M. Bulk density [(H-I)/(D-L)]: ___________ g/cm^3

Sample Number 2

A. Sample Depth: Top ___________ cm

B. Sample Depth: Bottom ___________ cm

C. Hole diameter: ___________ cm

D. Hole volume π x $(C/2)^2$ x (B-A) : ________ cm^3

E. Container weight: ___________ g

F. Wet weight of sample: ___________ g

G. Dry weight of sample: ___________ g

H. Dry soil weight (G-E): ___________ g

I. Weight of rocks: ___________ g

J. Volume of water without rocks: _________ mL

K. Volume of water and rocks: _________ mL

L. Volume of rocks (K-J): ___________ mL (cm^3)

M. Bulk density [(H-I)/(D-L)]: ___________ g/cm^3

Sample Number 3

A. Sample Depth: Top ___________ cm

B. Sample Depth: Bottom ___________ cm

C. Hole diameter: ___________ cm

D. Hole volume π x $(C/2)^2$ x (B-A) : ________ cm^3

E. Container weight: ___________ g

F. Wet weight of sample: ___________ g

G. Dry weight of sample: ___________ g

H. Dry soil weight (G-E): ___________ g

I. Weight of rocks: ___________ g

J. Volume of water without rocks: _________ mL

K. Volume of water and rocks: _________ mL

L. Volume of rocks (K-J): ___________ mL (cm^3)

M. Bulk density [(H-I)/(D-L)]: ___________ g/cm^3

Soil Investigation

Particle Size Distribution Data Work Sheet

Date of Sample Collection: ___________Site: _____________________________

Horizon Number:____________________Horizon Depth: Top _______ cm

Bottom _______ cm

Distance from 500 mL mark to base of graduated cylinder: ___________cm

Hydrometer Calibration Temperature_________ °C

Sample Number 1

A. 2 minute hydrometer reading: ________

C. 12 minute hydrometer reading: ________

B. 2 minute temperature: ___________ °C

D. 12 minute temperature: ___________ °C

E. 24 hour hydrometer reading: ___________

F. 24 hour temperature: ___________ °C

Sample Number 2

A. 2 minute hydrometer reading: ________

C. 12 minute hydrometer reading: ________

B. 2 minute temperature: ___________ °C

D. 12 minute temperature: ___________ °C

E. 24 hour hydrometer reading: ___________

F. 24 hour temperature: ___________ °C

Sample Number 3

A. 2 minute hydrometer reading: ________

C. 12 minute hydrometer reading: ________

B. 2 minute temperature: ___________ °C

D. 12 minute temperature: ___________ °C

E. 24 hour hydrometer reading: ___________

F. 24 hour temperature: ___________ °C

Soil Investigation
Soil pH Data Work Sheet

Date of Sample Collection: __________ Site: __________________________

pH Measurement method (check one): _____paper ______pen _____meter

---

Horizon Number:________

Horizon Depth: Top _____ cm

Bottom _____ cm

Sample Number 1

A. pH of water before adding soil: _____

B. pH of soil and water mixture: _____

Sample Number 2

A. pH of water before adding soil: _____

B. pH of soil and water mixture: _____

Sample Number 3

A. pH of water before adding soil: _____

B. pH of soil and water mixture: _____

Horizon Number:________

Horizon Depth: Top _____ cm

Bottom _____ cm

Sample Number 1

A. pH of water before adding soil: _____

B. pH of soil and water mixture: _____

Sample Number 2

A. pH of water before adding soil: _____

B. pH of soil and water mixture: _____

Sample Number 3

A. pH of water before adding soil: _____

B. pH of soil and water mixture: _____

Horizon Number:________

Horizon Depth: Top _____ cm

Bottom _____ cm

Sample Number 1

A. pH of water before adding soil: _____

B. pH of soil and water mixture: _____

Sample Number 2

A. pH of water before adding soil: _____

B. pH of soil and water mixture: _____

Sample Number 3

A. pH of water before adding soil: _____

B. pH of soil and water mixture: _____

Soil Investigation

Soil Fertility Data Work Sheet

Date of Sample Collection: ___________Site: ______________________________

Horizon Number:_________ Horizon Depth: Top _________cm

Bottom _________cm

Sample Number 1

Nitrate (N): High__ Med__ Low__ None__

Phosphorus (P): High__ Med__ Low__ None__

Potassium (K): High__ Med__ Low__ None__

Sample Number 2

Nitrate (N): High__ Med__ Low__ None__

Phosphorus (P): High__ Med__ Low__ None__

Potassium (K): High__ Med__ Low__ None__

Sample Number 3

Nitrate (N): High__ Med__ Low__ None__

Phosphorus (P): High__ Med__ Low__ None__

Potassium (K): High__ Med__ Low__ None__

Horizon Number:_________ Horizon Depth: Top _________cm

Bottom _________cm

Sample Number 1

Nitrate (N): High__ Med__ Low__ None__

Phosphorus (P): High__ Med__ Low__ None__

Potassium (K): High__ Med__ Low__ None__

Sample Number 2

Nitrate (N): High__ Med__ Low__ None__

Phosphorus (P): High__ Med__ Low__ None__

Potassium (K): High__ Med__ Low__ None__

Sample Number 3

Nitrate (N): High__ Med__ Low__ None__

Phosphorus (P): High__ Med__ Low__ None__

Potassium (K): High__ Med__ Low__ None__

Horizon Number:_________ Horizon Depth: Top _________cm

Bottom _________cm

Sample Number 1

Nitrate (N): High__ Med__ Low__ None__

Phosphorus (P): High__ Med__ Low__ None__

Potassium (K): High__ Med__ Low__ None__

Sample Number 2

Nitrate (N): High__ Med__ Low__ None__

Phosphorus (P): High__ Med__ Low__ None__

Potassium (K): High__ Med__ Low__ None__

Sample Number 3

Nitrate (N): High__ Med__ Low__ None__

Phosphorus (P): High__ Med__ Low__ None__

Potassium (K): High__ Med__ Low__ None__

Soil Investigation

Soil Moisture Study Site Work Sheet

Create a unique name for your site and give concise directions to it.

Site name: ____

Directions:____

____

Coordinates: LATITUDE:__________ LONGITUDE:__________ ELEV:________ m

Source of Lat/Lon (check one): GPS _____ Other _____

Site Metadata

Distance to nearest rain gauge or instrument shelter: ____ m; Direction ________
Distance to nearest Soil Characterization Sample Site: ____ m; Direction ________

State of Soil Moistur Study Site:
Natural ___, Plowed ___, Graded ___, Backfill ___, Compacted ___, Other ___

Surface Cover:
Bare Soil ___, Short grass (<10 cm) ___, Long grass (10 cm) ___

Canopy Cover:
Open ___, Some Trees within 30 m ___, Canopy Overhead ___
Structures within 30 m: No ___, Yes (describe size) ____________________

Soil Characterization:
(Take these values from the Soil Characterization Data Work Sheet for the nearest Soil Characterization Sample Site.)

	0-5 cm	10 cm	30 cm	60 cm	90 cm
Structure	________	________	________	________	________
Color	________	________	________	________	________
Consistence	________	________	________	________	________
Texture	________	________	________	________	________
Rocks:	________	________	________	________	________
Roots:	________	________	________	________	________
Bulk Density	________	________	________	________	________

Soil Particle Size Distribution:

% Sand	________	________	________	________	________
% Silt	________	________	________	________	________
% Clay	________	________	________	________	________

Did you choose USDA ________ or ISSS ________ definitions of sand and silt?

Land Cover Classification: (follow Land Cover protocol)

Most detailed MUC Code ______________________

Enter MUC Name ______________________

Collector's comments:

____

____

____

____

____

____

____

____

____

Site Sketch:

(Scale 1 square = ________)

Soil Investigation

Soil Moisture Data Work Sheet - Star Pattern

Site Name: ____

Name of Collector/Analyst/Recorder: ______________________________

Sample collection date: _______

time: _______ (hours and minutes) check one: UT___ Local ___

Current Conditions: Is soil saturated? Yes _____ No _____

Drying Method: 95-105° C oven ____; 75-95° C oven ____; microwave ____

Average Drying Time: _________(hours or minutes)

Bearing from Star Center (optional): ________ Distance from Star Center: ________

Observations:

Near-surface Samples:

Sample Number	Sample Depth	Container Number	A. Wet Weight (g)	B. Dry Weight (g)	C. Water Weight (A-B)	D. Container Weight (g)	E. Dry Soil Weight (B-D)	F. Soil Water Content (C/E)x100
1	0-5 cm	________	________	________	________	________	________	________
	10 cm	________	________	________	________	________	________	________
2	0-5 cm	________	________	________	________	________	________	________
	10 cm	________	________	________	________	________	________	________
3	0-5 cm	________	________	________	________	________	________	________
	10 cm	________	________	________	________	________	________	________

Depth Samples:

Sample Depth	Container Number	A. Wet Weight (g)	B. Dry Weight (g)	C. Water Weight (A-B)	D. Container Weight (g)	E. Dry Soil Weight (B-D)	F. Soil Water Content (C/E)x100
0-5 cm	________	________	________	________	________	________	________
10 cm	________	________	________	________	________	________	________
30 cm	________	________	________	________	________	________	________
60 cm	________	________	________	________	________	________	________
90 cm	________	________	________	________	________	________	________

Soil Investigation

Soil Moisture Data Work Sheet - Transect Pattern

Site Name: ____

Name of Collector/Analyst/Recorder: ______________________________

Sample collection date: ________

time: ________ (hours and minutes) check one: UT___ Local ___

Current Conditions: Is soil saturated? Yes ______ No ______

Drying Method: 95-105 °C oven ____; 75-95 °C oven ____; microwave ____

Average Drying Time: __________(hours or minutes)

Daily Metadata: (optional)

Length of Line: _________ m Compass Bearing: _______ Station Spacing: ______ m

Directions:

Transects should be 50 m long, located in an open field. Measurements are made 12 times/yr. during a regular interval of your choice. Enter the data for your samples collected between 0-5 cm (10 single samples plus 1 triple sample):

Observations:

Sample Number	Offset from end of Transect (m)	Container Number	A. Wet Weight (g)	B. Dry Weight (g)	C. Water Weight (A-B)	D. Container Weight (g)	E. Dry Soil Weight (B-D)	F. Soil Water Content (C/E)x100
1								
2								
3								
4								
3								
5								
6								
7								
8								
9								
10								
11								
12								
13								

Soil Investigation

Daily Gypsum Block Data Work Sheet

Site Name: ____

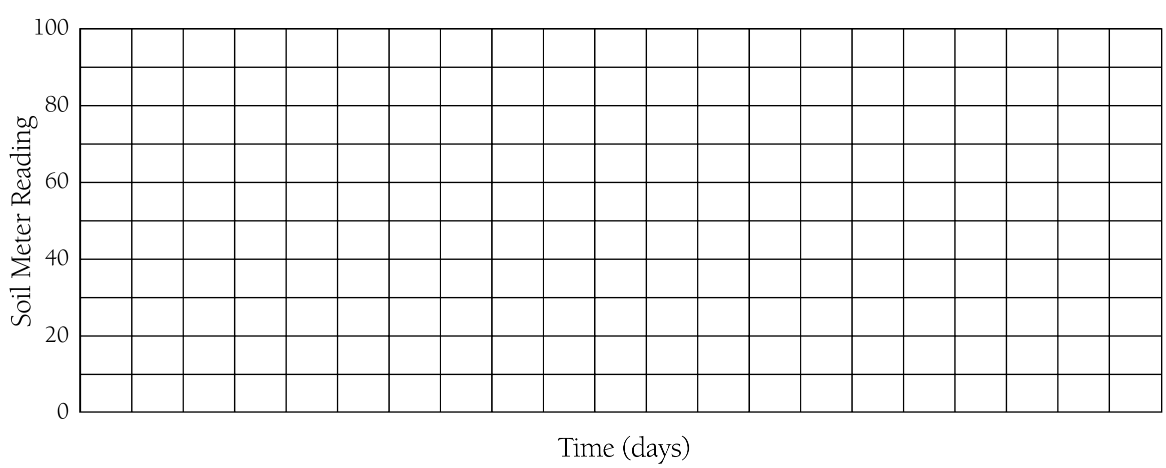
School Name and Address:____

GLOBE Teacher name: ____

Date you started to use this SWC calibration curve: ___________

Observations:

Measurement					Soil Moisture Meter Readings				SWC from Calibration Curve			
#	Date	Time (UT)	Is the soil saturated? Yes or No	Observers' Names	10 cm	30 cm	60 cm	90 cm	10 cm	30 cm	60 cm	90 cm
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												



Soil Investigation

Annual Gypsum Block Calibration Data Work Sheet

Site Name: ____

School Name and Address:______________________________________

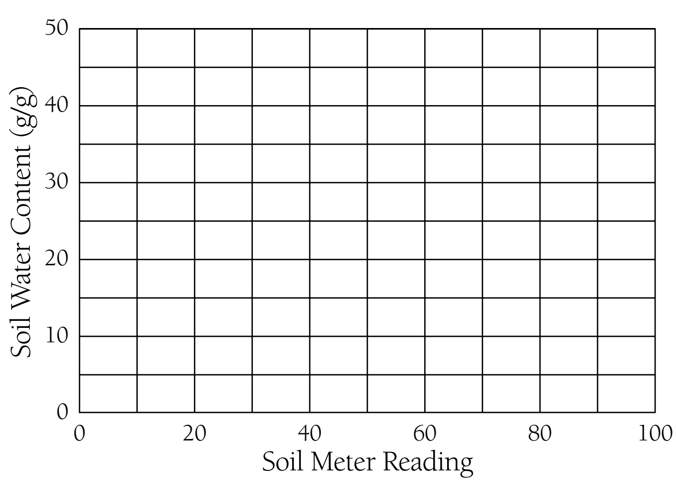
GLOBE Teacher name: ____

Drying Method (check one): 95-105 °C oven ___; 75-95 °C oven ___; microwave____

Average Drying Time: _________ (hours or minutes)

Observations:

Measurement				Data for 30 cm depth only						
#	Date	Time (UT)	Observers' Name	A. Wet Weight (g)	B. Dry Weight (g)	C. Water Weight (A-B)	D. Can Weight (g)	E. Dry Soil Weight (B-D)	F. Soil Water Content (C/E)x100	G. Meter Reading
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										



Soil Investigation

Soil Infiltration Data Work Sheet

Site Name: ____

Name of Collector/Analyst/Recorder: ______________________________

Sample collection date: ________

time: ________ (hours and minutes) check one: UT___ Local ___

Distance to Soil Moisture study site marker ______ m

Sample Set number: _________ Width of your reference band: _______ mm

Diameter: Inner Ring: _______ cm Outer Ring: ________ cm

Heights of reference band above ground level: Upper : ______ mm Lower : _______ mm

Saturated Soil Water Content below infiltrometer after the experiment:

A. Wet Weight: ______ g B. Dry Weight: ______ g C. Water Weight (A–B): ______ g

D. Container Weight: ______ g E. Dry Soil Weight (B–D): ______ g F. Soil Water Content (C/E) x 100 ______

Daily Metadata/Comments: (optional)

Directions:

Take 3 sets of infiltration rate measurements within a 5 m diameter area. Use a different data work sheet for each set. Each set consists of multiple timings of the same water level drop or change until the flow rate becomes constant or 45 minutes is up. Record your data below for one set of infiltration measurements you take.

The form below is setup to help you calculate the flow rate.

For data analysis, plot the Flow Rate (F) vs. Midpoint time (D).

Observations:

	A. Start		B. End		C. Interval (min) (B-A)	D. Midpoint (min) (A+C/2)	E. Water Level Change (mm)	F. Flow Rate (mm/min) (E/C)
	(min)	(sec)	(min)	(sec)				
1	___	___	___	___	________	________	________	________
2	___	___	___	___	________	________	________	________
3	___	___	___	___	________	________	________	________
4	___	___	___	___	________	________	________	________
5	___	___	___	___	________	________	________	________
6	___	___	___	___	________	________	________	________
7	___	___	___	___	________	________	________	________
8	___	___	___	___	________	________	________	________
9	___	___	___	___	________	________	________	________

Soil Investigation

Soil Temperature Data Work Sheet

Site Name: ____

Name of Collector/Analyst/Recorder: ______________________________

Sample collection date: ________

time: ________ (hours and minutes) check one: UT___ Local ___

Soil Thermometer: Dial _______ Digital _______ Other ______

Current Conditions: Rain within last 24 hours? Yes ______ No ______

Daily Metadata/Comments: (optional)

Directions:

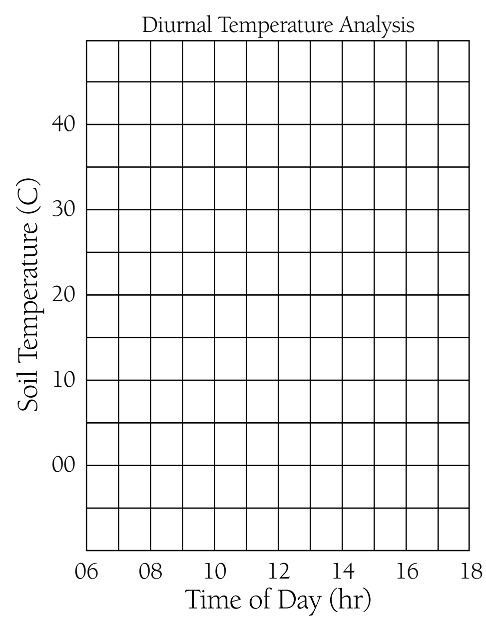
Take 3 sets of soil temperature measurements adjacent to your soil moisture STAR pattern or Atmosphere Instrument Shelter at 5 and 10 cm depth on a weekly basis. Use sample lines 1-3 below (3 samples x 2 depths = 6 measurements). Complete these measurements within 20 minutes of one another and within 1 hour of local solar noon.

OR

Measure the diurnal variation of soil temperature seasonally or at least 3 times/yr. by measuring soil temperature at 5 and 10 cm every 2 to 3 hours during the daytime. Use as many sample lines below as you have measurement times (try to have at least 5). This must be done on two consecutive days. Report each day separately. Additional space is available for classes who want to report diurnal data more frequently or for more hours. Use the graph below to plot soil temperature vs. time-of-day.

Observations:

Sample	**Time**		**Temperature**	
No.	(hr)	(min)	5cm (C)	10 cm (C)
1	______	______	______	______
2	______	______	______	______
3	______	______	______	______
4	______	______	______	______
5	______	______	______	______
6	______	______	______	______
7	______	______	______	______
8	______	______	______	______

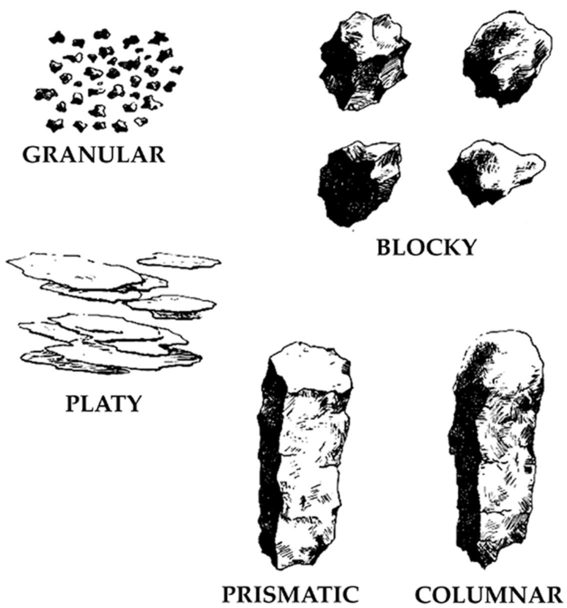


Soil Investigation

Soil Characterization Information Sheet

A: Soil Structure

Take a sample of undisturbed soil in your hand (either from the pit or from the shovel or auger). Look closely at the soil in your hand and examine its structure. Soil structure is the shape that the soil takes based on its physical and chemical properties. Each individual unit of soil structure is called a ped. Some possible choices of soil structure are:



Choices of Soil Structure

Sometimes, your soil may be structureless, which means that within a horizon, soil peds may not have a shape. In this case, the soil structure may be single grained or massive. Single grained is like sand at a beach or in a playground where there are individual sand particles that do not stick together. Massive is when the soil sticks together in a large mass that does not break in any pattern.

It is common to see more than one type of structure in a soil sample. Record on your data sheets only the structure type that is most common in your sample. Discuss and agree upon the main structure type you see. If the sample is structureless, record whether it is single-grained or massive.

B: Soil Color

Take a ped from each horizon and note on the data sheet whether it is moist, dry, or wet. If it is dry, moisten it slightly with water from your water bottle. Break the ped and compare the color of the inside surface with the soil color chart. Stand with the sun over your shoulder so that sunlight shines on the color chart and the soil sample you are examining. Record on the data sheet the code (letter and number) of the color on the chart that most closely matches the soil's color. Sometimes, a soil sample may have more than one color. Record a maximum of two colors if necessary, and indicate (1) the Main Color, and (2) the Second Color. Again, reach an agreement on these colors.

C: Soil Consistence

Take a ped from the soil horizon. Record on the data sheet whether the ped is moist, wet or dry. If the soil is very dry, moisten the face of the profile using a water bottle with a squirt top, and then remove a ped for determining consistence. Holding it between your thumb and forefinger, gently squeeze it until it pops or falls apart. Record one of the following categories of soil ped consistence on the data work sheet.

Loose: You have trouble picking out a single ped and the structure falls apart before you handle it.

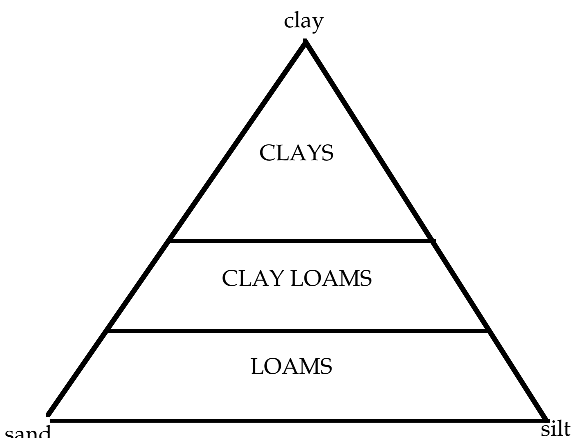
Friable: The ped breaks with a small amount of pressure.

Fim: The ped breaks when you apply a good amount of pressure and dents your fingers before it breaks.

Extremely Fim: The ped can not be crushed with your fingers (you need a hammer!).

D: Soil Texture

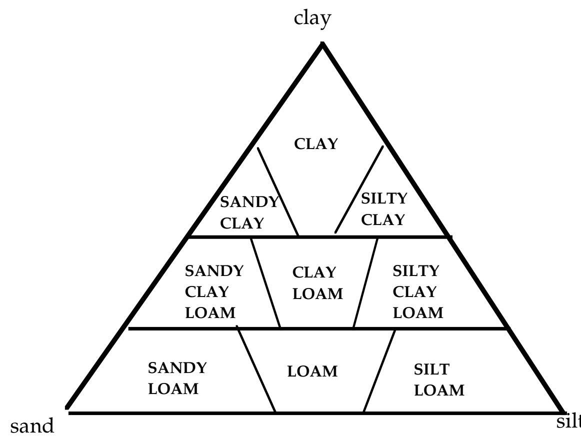
The texture of a soil describes the way the soil feels when you rub it between your fingers. The texture differs depending on the size of the particles in the soil. Sand, silt, and clay are names that describe the size of individual particles in the soil. Sand is the largest size and feels gritty to touch. Silt is medium size and feels *floury* or silky. Clay is the smallest size particle and feels sticky or hard to squeeze. It is more common to find a combination of these different particle sizes in a soil sample. Use the following procedure and the 2 textural triangles below to determine the texture name of each soil horizon in the profile.



Textural Triangle 1

1. Take a sample of soil about the size of a golf ball and add enough water to moisten it. Work it between your fingers until it is the same moisture throughout. Then, squeeze it between your thumb and forefinger in a snapping motion to try to form a ribbon of soil.
2. Refer to Textural Triangle 1 and feel for clay. Clay feels extremely sticky (sticks to your hands and is hard to work), is stiff and requires a lot of thumb and finger pressure to form a ribbon. If this is what your sample feels like, it should be classified as a clay, as shown on Textural Triangle 1.
3. If the soil feels slightly sticky and a little softer to squeeze, it is classified as a clay loam on Textural Triangle 1 and consists of clay, silt and sand particles.
4. If the soil is soft, smooth, and easy to squeeze, it is classified as a loam on Textural Triangle 1.

Next, refine your texture name using Textural Triangle 2:



Textural Triangle 2

1. Feel the same soil sample, but focus on the feeling of sand. If the soil feels very smooth, with no sandy grittiness, add either the word silt or silty to your classification (from Textural Triangle 1), such as silty clay, as shown on Textural Triangle 2. This means that your soil sample has more silt-size particles than sand-size particles.
2. If the soil feels very gritty, add the term sandy to your original soil classification (from Textural Triangle 1), such as sandy clay, as shown on Textural Triangle 2. This means your soil sample has more sand size particles than silt size particles.
3. If you feel some sand, but not a lot, this means it has approximately the same amounts of sand and silt size particles. Your original classification from Textural Triangle 1 (clay, clay loam, or loam) remains the same.

The soil texture can also feel different depending on how wet or dry it is, how much organic matter is in it, and the kind of clay minerals in it. When feeling the soil texture, be sure to add the same amount of water to each soil sample so that you can more accurately compare textures to each other.

Record on the data work sheet the name of the soil texture that the students agree on. If it is close between two different types of texture, list both. Also, note whether the sample was dry, wet, or moist when it was examined.

E. Presence of Roots

Observe and record if there are none, few, or many roots in the horizon

F. Presence of Rocks

Observe and record if there are none, few, or many rocks in the horizon. A rock is defined as being larger than 2 mm in size.

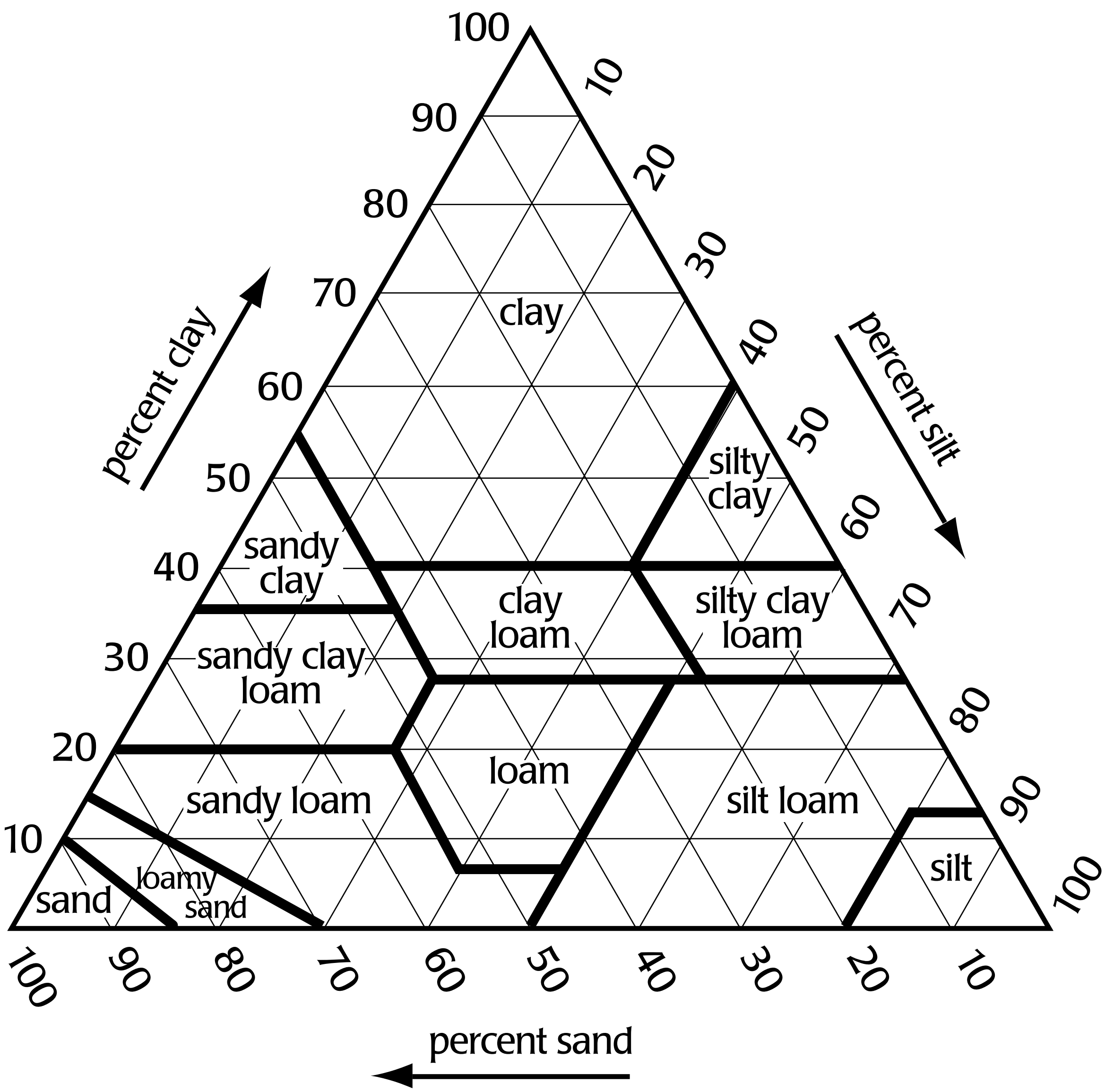
G. Test for Free Carbonates

Perform this test by squirting vinegar on the soil. If carbonates are present, there will be a chemical reaction between the vinegar and the carbonates to produce carbon dioxide. When carbon dioxide is produced, it bubbles or *effervesces*. The more carbonates that are present, the more bubbles (*effervescence*) you will observe.

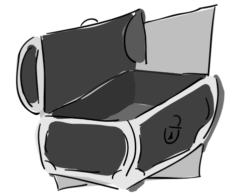
1. Look carefully at your soil profile for white coatings on the soil and rocks which might indicate that free carbonates are present.
2. Set aside a portion of the pit or sample from the auger hole which you do not touch with your hands and use it for the free carbonates test.
3. After you have finished characterizing the other soil properties, test for free carbonates. Open the acid bottle and starting from the bottom of the profile and moving up, squirt vinegar on the soil particles. Observe carefully for the presence of effervescence.
4. For each horizon record one of the following as the results of the Free Carbonate Test:
   - <u>None:</u> if you observe no reaction, the soil has no free carbonates present.
   - <u>Slight:</u> if you observe a very slight bubbling action; this indicates the presence of some carbonates.
   - <u>Strong:</u> if there is a strong reaction (many, large bubbles) this indicates that many carbonates are present.
5. If you used the auger technique, place the sample back into the hole when you are finished. Do not bring it back to the classroom.

Soil Investigation

Textural Triangle 3



Glossary



alluvial
Transported by water from one place to another.

columnar
A type of soil structure where the soil peds (or chunks) are in the shape of a column with a rounded top. This is found in arid regions.

concretion
A nodule composed of concentrated chemicals in a soil (e.g. iron oxides, manganese oxides, calcium carbonates).

dissolution
Soils, among other compounds, start dissolving into smaller units when placed in contact with water.

dinural cycle
A daily cycle, a basic repetition period of 24 hours. All processes that are dominated by the sun are dinural. Tides, in contrast, repeat cycles twice daily.

effervescence
The bubbling action that occurs as a gas comes out of a liquid for example when the carbon dioxide gas caused by the reaction of carbonate coatings on soil with an acid bubbles through acidic liquid.

eluviation
The removal of materials in one horizon which are then "illuviated" or deposited into a lower horizon.

erosion
The removal and movement of soil materials by water, wind, ice, or gravity as well as by human activities such as agriculture or construction.

evaporation
Water on Earth's surface or in the soil absorbs heat from the sun to the point that it vaporizes or evaporates and becomes part of the atmosphere.

face
The way an exposed section of soil or soil profile appears.

floury
Having the feel of wheat flour – smooth and powdery.

free carbonates
Carbonate materials that form coatings on soil that react with an acid to form carbon dioxide gas.

friable
A type of soil consistence in which the soil ped "pops" when squeezed between the thumb and fore finger with a small amount of pressure.

gravimetric
Relating to measurement by weight or variations in a gravitational field.

horizon
An individual layer within the soil which has its own unique characteristics (such as color, structure, texture, or other properties) that make it different from the other layers in the soil profile.

humus
The part of the soil profile that is composed of decomposed organic matter from dead and decaying plants and animals.

hydrometer
An instrument based on the principles of buoyancy used to measure the specific gravity of a liquid in relation to the specific gravity os pure water at a specified temperature.

illuviation
The deposit of materials carried by water from one horizon into another within the soil (such as clay or nutrients in solution).

in situ
Latin for the original position.

lithosphere
The outer layer of soul and rock on a planet is called the "lithosphere" after the Greek word "lithos" meaning "stone."

litter
The covering over the soil in a forest made up of leaves, needles, twigs, branches, stems, and fruits from the surrounding trees.

metadata
Data about data. Soil moisture data requires metadata describing the vegetation cover and possible sources of water in order to be interpreted properly.

nomenclature
A particular naming convention agreed to by many individuals or scientists.

organic matter
Any plant or animal material added to the soil.

particle size distribution
The amount (percent) of each of sand, silt, and clay in a soil sample.

ped
An individual unit of natural soil structure or aggregation (such as granular, blocky, columnar, prismatic, or platey).

pedogenesis
The formation of soil profiles depending on the five soil-forming factors (climate, parent material, topography, organisms, and time) to create the Pedosphere.

pedosphere
The thin outer layer of the Earth which is made up of soil. The pedosphere acts as an integrator between the atmosphere, biosphere, lithosphere, and hydrosphere of the Earth.

prismatic
A type of soil structure in which the soil ped is in the shape of a prism.

soil consistence
How easy or hard it is for a soil ped to break apart when it is squeezed.

soil horizons
An identifiable soil unit due to color, structure, or texture.

soil profile
The "face" of a soil when it has been cut vertically that shows the individual horizons and soil properties with depth.

soil structure
The shape of soil units (peds) that occur naturally in a soil horizon. Some possible soil structures are granular, blocky, prismatic, columnar, or platy. Soils can also be structureless if they do not form into peds. In this case, they may be a consolidated mass (massive) or stay as individual particles (single-grained).

soil texture
The way soil "feels" when it is squeezed between the fingers or in the hand. The texture depends on the amount of sand, silt, and clay in the sample (particle size distribution), as well as other factors (how wet it is, how much organic matter is in the sample, the kind of clay, etc.)

subsoil
The common term for the layers beneath the topsoil.

supernatant
Liquid above the settled soil that is cleaner than the soil

topsoil
The common term for the top layer of soil.

transect
In any field (outdoor) study, a transect consists of a line of study, often divided into intervals where observations or samples are collected.

transpiration
Water in plants escapes or transpires into the atmosphere as the leaf stomates open to exchange carbon for oxygen.

uniform
This term is used in its traditional sense that some characteristic displays similar properties, Two related words are homogeneous (distributed evenly) and normal (distributed about a central mean value and described by a statistical equation).

Soil Investigation

Soil Characterization Sample Site Data Entry Sheet

School Name

Measurement Time:
Year: [ ] **Month:** [Select] **Day:** [ ] **Hour:** [ ] **UT**
Current Time: 1997 June 18, 20 UT

Name of site: [ ]
Create a unique name that describes the location of your site.

Please supply as much of the following information as you can now. When you obtain additional information click on the Data Entry button and go to "Edit a Study Site".

Source of data: ○ **GPS** ○ **Other**

Latitude: [ ] deg [ ] min ○ **North** ○ **South** of the Equator
(Enter the data in the format 56 deg 12.84 min **and** mark whether it is North or South.)

Longitude: [ ] deg [ ] min ○ **East** ○ **West** of the Prime Meridian
(Enter the data in the format 102 deg 43.90 min **and** mark whether it is East or West.)

Elevation: [ ] meters

Slope of Site: [ ] degrees

Soil Samples are taken from: ○ Soil Pit ○ Auger Hole ○ 10cm of the Soil Surface ○ Excavation ○ Road Cut ○ Other Source

The Site Location is: ☐ Near the Soil Moisture Study Site ☐ Near the Surface Water Study Site ☐ In or Near the Biology Study Site ☐ Other

Parent Material of Soil (if known): ○ Bedrock ○ Glacial Deposit ○ Volcanic Deposit ○ Stream Deposit ○ Wind Blown Sand ○ Ancient Lake Deposit ○ Marine Deposit ○ Colluvium Deposit ○ Other ○ Don't Know

Enter the most detailed MUC level MUC Code : [ ]

Enter MUC Name : [ ]

[Send] [Erase]

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School Name

Measurement Time:

Year: [ ] **Month:** [Select] **Day:** [ ] **Hour:** [ ] **UT**

Current Time: June 18, 1997, 20 UT

Sample Site Location: [03Tester2000]

After you Send the data below, you will be given a menu for you to enter your remaining Soil Characterization data.

Horizon number (starting from the top): [ ]

Soil Horizon: ○ **O** ○ **A** ○ **E** ○ **B** ○ **C** ○ **R**

Top Depth (cm): [ ] **Bottom Depth (cm):** [ ]

[Send] [Erase]

NOAA/Forecast Systems Laboratory, Boulder,Colorado

Soil Horizon Description Data Entry Sheet

School Name

Measurement Date : May 14, 1997
Measurement Time : 14 UT
Sample Site Location : Tester2000
Horizon Number : 1

Moisture Status : Unknown

Structure : Unknown

Main Color : **Other Color :**
Example of the Color input (Hue:Value/Chroma): 7.5R:2.5/2

Consistence : Unknown

Texture : Unknown

Rocks : Unknown

Roots : Unknown

Carbonates : Unknown

Comments:

Send Erase

NOAA/Forecast Systems Laboratory, Boulder,Colorado

Soil Investigation

Soil Characterization Data Entry Sheet

Soil Bulk Density Data Entry Sheet

School Name

Measurement Date : May 14, 1997
Measurement Time : 14 UT
Sample Site Location : Tester2000
Horizon Number : 1

Sample 1

For Pit Method :
Volume of Sample: ______ mL

For Auger Method :
Sample Top Depth : ______ cm
Sample Bottom Depth: ______ cm
Hole Diameter: ______ cm

Weight of moist soil and container: ______ g
Weight of dry soil and container: ______ g
Weight of empty container: ______ g
Weight of rocks contained in dry soil sample: ______ g
Volume of water before addition of rocks: ______ mL
Volume of water after addition of rocks: ______ mL

Bulk Density: ______ g/mL

Sample 2

For Pit Method :
Volume of Sample: ______ mL

For Auger Method :
Sample Top Depth: ______ cm
Sample Bottom Depth : ______ cm
Hole Diameter: ______ cm

Weight of moist soil and container: ______ g
Weight of dry soil and container: ______ g
Weight of empty container: ______ g
Weight of rocks contained in dry soil sample: ______ g
Volume of water before addition of rocks: ______ mL
Volume of water after addition of rocks: ______ mL

Bulk Density: ______ g/mL

Sample 3

For Pit Method :

Volume of Sample: [ ] mL

For Auger Method :

Sample Top Depth: [ ] cm

Sample Bottom Depth: [ ] cm

Hole Diameter: [ ] cm

Weight of moist soil and container: [ ] g

Weight of dry soil and container: [ ] g

Weight of empty container: [ ] g

Weight of rocks contained in dry soil sample: [ ] g

Volume of water before addition of rocks: [ ] mL

Volume of water after addition of rocks: [ ] mL

Bulk Density: [ ] g/mL

Comments:

[ ]

NOAA/Forecast Systems Laboratory, Boulder,Colorado

Soil Particle-Size Distribution 1996 Method Data Entry Sheet

School Name

Measurement Date : May 14, 1997
Measurement Time : 14 UT
Sample Site Location : Tester2000
Horizon Number : 1

<u>Sample 1</u>
Total Soil (mL): [ ] **40 Seconds (mL):** [ ] **30 Minutes (mL):** [ ]

<u>Sample 2</u>

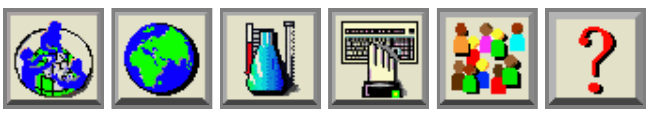
Total Soil (mL): [ ] **40 Seconds (mL):** [ ] **30 Minutes (mL):** [ ]

<u>Sample 3</u>

Total Soil (mL): [ ] **40 Seconds (mL):** [ ] **30 Minutes (mL):** [ ]

Comments:
[ ]

Send Erase



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Soil Particle Size Distribution Hydrometer Method Data Entry Sheet

School Name

Measurement Date : May 14, 1997
Measurement Time : 14 UT
Sample Site Location : Tester2000
Horizon Number : 1

Temperature the Hydrometer was calibrated: 15.5 degrees Celsius
Distance between 500 mL line to base of cylinder: ____ cm

Sample 1

Hydrometer Readings:

2 minutes: ____ (USDA standard for silt and clay left in suspension)
12 minutes: ____ (ISSS standard for silt and clay left in suspension)
24 hours: ____ (Clay left in suspension)

Temperature of Water and Soil Mixture:

2 minutes: ____ degrees C
12 minutes: ____ degrees C
24 hours: ____ degrees C

Sample 2

Hydrometer Readings:

2 minutes: ____ (USDA standard for silt and clay left in suspension)
12 minutes: ____ (ISSS standard for silt and clay left in suspension)
24 hours: ____ (Clay left in suspension)

Temperature of Water and Soil Mixture:

2 minutes: ____ degrees C
12 minutes: ____ degrees C
24 hours: ____ degrees C

Sample 3

Hydrometer Readings:

2 minutes: ____ (USDA standard for silt and clay left in suspension)
12 minutes: ____ (ISSS standard for silt and clay left in suspension)
24 hours: ____ (Clay left in suspension)

Temperature of Water and Soil Mixture:

2 minutes: ☐ degrees C
12 minutes: ☐ degrees C
24 hours: ☐ degrees C

Comments:

NOAA/Forecast Systems Laboratory, Boulder,Colorado

Soil pH Data Entry Sheet:

School Name

Measurement Date : May 14, 1997
Measurement Time : 14 UT
Sample Site Location : Tester2000
Horizon Number : 1

---

pH of Distilled Water before Soil is Added:
Test 1: [ ] **Test 2:** [ ] **Test 3:** [ ]

pH of Soil and Water:
Test 1: [ ] **Test 2:** [ ] **Test 3:** [ ]

Measured With : Select

Comments:

Send Erase

NOAA/Forecast Systems Laboratory, Boulder,Colorado

Soil Fertility Data Entry Sheet

School Name

Measurement Date : May 14, 1997
Measurement Time : 14 UT
Sample Site Location : Tester2000
Horizon Number : 1

Sample 1

Nitrogen : Unknown

Phosphorus : Unknown

Potassium : Unknown

Sample 2

Nitrogen : Unknown

Phosphorus : Unknown

Potassium : Unknown

Sample 3

Nitrogen : Unknown

Phosphorus : Unknown

Potassium : Unknown

Comments:

Send Erase

NOAA/Forecast Systems Laboratory, Boulder,Colorado

Soil Investigation

Soil Moisture Study Site Data Entry Sheet

School Name

Measurement Time:
Year: [ ] **Month:** [Select] **Day:** [ ] **Hour:** [ ] **UT**
Current Time: 1997 June 18, 20 UT

Name of site: [ ]
Create a unique name that describes the location of your site.

Please supply as much of the following information as you can now. When you obtain additional information click on Entry button and go to "Edit a Study Site".

Source of data: ○ **GPS** ○ **Other**

Latitude: [ ] deg [ ] min ○ **North** ○ **South** of the Equator
(Enter the data in the format 56 deg 12.84 min **and** mark whether it is North or South.)

Longitude: [ ] deg [ ] min ○ **East** ○ **West** of the Prime Meridian
(Enter the data in the format 102 deg 43.90 min **and** mark whether it is East or West.)

Elevation: [ ] meters

Distance of Site to Instrument Shelter: [ ] meters
Direction: ○ N ○ NE ○ E ○ SE ○ S ○ SW ○ W ○ NW

Distance to Nearest Soil Characterization Hole: [ ] meters
Direction: ○ N ○ NE ○ E ○ SE ○ S ○ SW ○ W ○ NW

Surface of Soil Site: ○ Natural ○ Plowed ○ Graded ○ Backfill ○ Compacted ○ Other

Surface Cover: ○ Bare Soil ○ Short Grass (< 10cm) ○ Long Grass (> 10cm)

Canopy Cover: ○ Open ○ Some Trees Within 30m ○ Canopy Overhead

Average Soil Characteristics: Sand [ ] % Silt [ ] % Clay [ ] %

Rocks: ○ None ○ Few ○ Many

Roots: ○ None ○ Few ○ Many

Enter the most detailed MUC level MUC Code : [ ]

Enter MUC Name : [ ]

[Send] [Erase]

Near Surface Star Protocol

School Name

Measurement Time:
Year: **Month:** Select **Day:** **Hour:** **UT**
Current Time: 1997 June 18, 20 UT

Study Site Location: 431 m south of weather station at President''s house

Is soil saturated? ◯ Yes ◯ No

Drying Method: Select One
Average Drying Time Hours: **Minutes:**

Enter the data for your three samples at a depth between 0 and 5 cm:

Container Number: 1: 2: 3:
Weight of Wet Soil and Container (g): 1: 2: 3:
Weight of Dry Soil and Container (g): 1: 2: 3:
Weight of Empty Container (g): 1: 2: 3:

Soil Water Content (g/g x 100): 1: 2: 3:

Enter the data for your three samples taken at a depth of 10 cm:

Container Number: 1: 2: 3:
Weight of Wet Soil and Container (g): 1: 2: 3:
Weight of Dry Soil and Container (g): 1: 2: 3:
Weight of Empty Container (g): 1: 2: 3:

Soil Water Content (g/g x 100): 1: 2: 3:

Comments:

Send Erase

NOAA/Forecast Systems Laboratory, Boulder,Colorado

Near Surface Transect Protocol

School Name

Measurement Time:
Year: [ ] **Month:** [Select] **Day:** [ ] **Hour:** [ ] **UT**
Current Time: 1997 June 18, 20 UT

Study Site Location: [431 m south of weather station at President''s house]

Is soil saturated? ○ Yes ○ No

Drying Method: [Select One]
Average Drying Time Hours: [ ] **Minutes:** [ ]

Enter the data for your samples taken at a depth between 0 and 5 cm (10 single samples plus 1 triple sample):

<u>Sample 1:</u>
Container Number: [ ]
Offset Distance from End of Transect(m): [ ]
Weight of Wet Soil and Container (g): [ ]
Weight of Dry Soil and Container (g): [ ]
Weight of Empty Container (g): [ ]
Soil Water Content(g/g x 100): [ ]

<u>Sample 2:</u>
Container Number: [ ]
Offset Distance from End of Transect: [ ]
Weight of Wet Soil and Container (g): [ ]
Weight of Dry Soil and Container (g): [ ]
Weight of Empty Container (g): [ ]
Soil Water Content(g/g x 100): [ ]

<u>Sample 3:</u>
Container Number: [ ]
Offset Distance from End of Transect: [ ]
Weight of Wet Soil and Container (g): [ ]
Weight of Dry Soil and Container (g): [ ]
Weight of Empty Container (g): [ ]
Soil Water Content(g/g x 100): [ ]

<u>Sample 4:</u>
Container Number: [ ]
Offset Distance from End of Transect: [ ]

Weight of Wet Soil and Container (g):
Weight of Dry Soil and Container (g):
Weight of Empty Container (g):
Soil Water Content(g/g x 100):

<u>Sample 5:</u>
Container Number:
Offset Distance from End of Transect:
Weight of Wet Soil and Container (g):
Weight of Dry Soil and Container (g):
Weight of Empty Container (g):
Soil Water Content(g/g x 100):

<u>Sample 6:</u>
Container Number:
Offset Distance from End of Transect:
Weight of Wet Soil and Container (g):
Weight of Dry Soil and Container (g):
Weight of Empty Container (g):
Soil Water Content(g/g x 100):

<u>Sample 7:</u>
Container Number:
Offset Distance from End of Transect:
Weight of Wet Soil and Container (g):
Weight of Dry Soil and Container (g):
Weight of Empty Container (g):
Soil Water Content(g/g x 100):

<u>Sample 8:</u>
Container Number:
Offset Distance from End of Transect:
Weight of Wet Soil and Container (g):
Weight of Dry Soil and Container (g):
Weight of Empty Container (g):
Soil Water Content(g/g x 100):

<u>Sample 9:</u>
Container Number:
Offset Distance from End of Transect:
Weight of Wet Soil and Container (g):
Weight of Dry Soil and Container (g):
Weight of Empty Container (g):
Soil Water Content(g/g x 100):

<u>Sample 10:</u>
Container Number:
Offset Distance from End of Transect:
Weight of Wet Soil and Container (g):
Weight of Dry Soil and Container (g):

Weight of Dry Soil and Container (g):
Weight of Empty Container (g):
Soil Water Content(g/g x 100):

Sample 11:
Container Number:
Offset Distance from End of Transect:
Weight of Wet Soil and Container (g):
Weight of Dry Soil and Container (g):
Weight of Empty Container (g):
Soil Water Content(g/g x 100):

Sample 12:
Container Number:
Offset Distance from End of Transect:
Weight of Wet Soil and Container (g):
Weight of Dry Soil and Container (g):
Weight of Empty Container (g):
Soil Water Content(g/g x 100):

Sample 13:
Container Number:
Offset Distance from End of Transect:
Weight of Wet Soil and Container (g):
Weight of Dry Soil and Container (g):
Weight of Empty Container (g):
Soil Water Content (g/g x 100):

Comments:

NOAA/Forecast Systems Laboratory, Boulder,Colorado

Depth and Gypsum Block Protocols

School Name

Measurement Time:
Year: [ ] **Month:** [Select] **Day:** [ ] **Hour:** [ ] **UT**
Current Time 1997 June 18, 20 UT

Study Site Location: [431 m south of weather station at President''s house]

Is soil saturated? ○ Yes ○ No
Average Drying Time Hours: [ ] **Minutes:** [ ]

Drying Method: [Select One]

Date these gypsum blocks were installed:
Year: [ ] **Month:** [Select]

Enter Depth Protocol data, Gypsum Block Protocol data, or both.

<u>Sample between 0-5 cm:</u>

DEPTH PROFILE:
Container Number: [ ]
Weight of Wet Soil and Container (g): [ ]
Weight of Dry Soil and Container (g): [ ]
Weight of Empty Container (g): [ ]
Soil Water Content (g/g x 100): [ ]

GYPSUM BLOCK PROTOCOL:
Soil Moisture Meter Reading: [ ]
Calibration Curve Soil Water Content (g/g x 100): [ ]

<u>Sample at 10 cm:</u>

DEPTH PROFILE:
Container Number: [ ]
Weight of Wet Soil and Container (g): [ ]
Weight of Dry Soil and Container (g): [ ]
Weight of Empty Container (g): [ ]
Soil Water Content (g/g x 100): [ ]

GYPSUM BLOCK PROTOCOL:
Soil Moisture Meter Reading: [ ]
Calibration Curve Soil Water Content (g/g x 100): [ ]

Sample at 30 cm:

DEPTH PROFILE:
Container Number:
Weight of Wet Soil and Container (g):
Weight of Dry Soil and Container (g):
Weight of Empty Container (g):
Soil Water Content (g/g x 100):

GYPSUM BLOCK PROTOCOL:
Soil Moisture Meter Reading:
Calibration Curve Soil Water Content (g/g x 100):

Sample at 60 cm:

DEPTH PROFILE:
Container Number:
Weight of Wet Soil and Container (g):
Weight of Dry Soil and Container (g):
Weight of Empty Container (g):
Soil Water Content (g/g x 100):

GYPSUM BLOCK PROTOCOL:
Soil Moisture Meter Reading:
Calibration Curve Soil Water Content (g/g x 100):

Sample at 90 cm:

DEPTH PROFILE:
Container Number:
Weight of Wet Soil and Container (g):
Weight of Dry Soil and Container (g):
Weight of Empty Container (g):
Soil Water Content (g/g x 100):

GYPSUM BLOCK PROTOCOL:
Soil Moisture Meter Reading:
Calibration Curve Soil Water Content (g/g x 100):

Comments:

NOAA/Forecast Systems Laboratory, Boulder,Colorado

School Name

Measurement Time:
Year: [ ] **Month:** [Select] **Day:** [ ] **Hour:** Enter hour below
Current Time: 1997 June 18, 20 UT

Study Site Location: [SM43 1 m south of weather station at President''s house (Soil Mois. Site)]

Enter all soil temperature data recorded in one day:

Soil Thermometer: [Select]

Has there been rain within the last 24 hours? ○ Yes ○ No

Sample 1:
Hour of Measurement (UT): [ ] **Minutes:** [0]
Temperature at 5 cm: [ ] degrees C
Temperature at 10 cm: [ ] degrees C

Sample 2:
Hour of Measurement (UT): [ ] **Minutes:** [0]
Temperature at 5 cm: [ ] degrees C
Temperature at 10 cm: [ ] degrees C

Sample 3:
Hour of Measurement (UT): [ ] **Minutes:** [0]
Temperature at 5 cm: [ ] degrees C
Temperature at 10 cm: [ ] degrees C

Sample 4:
Hour of Measurement (UT): [ ] **Minutes:** [0]
Temperature at 5 cm: [ ] degrees C
Temperature at 10 cm: [ ] degrees C

Sample 5:
Hour of Measurement (UT): [ ] **Minutes:** [0]
Temperature at 5 cm: [ ] degrees C
Temperature at 10 cm: [ ] degrees C

Sample 6:
Hour of Measurement (UT): [ ] **Minutes:** [0]
Temperature at 5 cm: [ ] degrees C
Temperature at 10 cm: [ ] degrees C

Sample 7:

Hour of Measurement (UT): [ ] **Minutes:** [0]
Temperature at 5 cm: [ ] degrees C
Temperature at 10 cm: [ ] degrees C

<u>Sample 8:</u>
Hour of Measurement (UT): [ ] **Minutes:** [0]
Temperature at 5 cm: [ ] degrees C
Temperature at 10 cm: [ ] degrees C

<u>Sample 9:</u>
Hour of Measurement (UT): [ ] **Minutes:** [0]
Temperature at 5 cm: [ ] degrees C
Temperature at 10 cm: [ ] degrees C

<u>Sample 10:</u>
Hour of Measurement (UT): [ ] **Minutes:** [0]
Temperature at 5 cm: [ ] degrees C
Temperature at 10 cm: [ ] degrees C

<u>Sample 11:</u>
Hour of Measurement (UT): [ ] **Minutes:** [0]
Temperature at 5 cm: [ ] degrees C
Temperature at 10 cm: [ ] degrees C

Comments:

NOAA/Forecast Systems Laboratory, Boulder,Colorado

Soil Investigation

Soil Infiltration Data Entry Sheet

School Name

Measurement Time:
Year: [ ] **Month:** [Select] **Day:** [ ] **Hour:** [ ] UT
Current Time: 1997 June 18, 20 UT

Study Site Location: [SM43 1 m south of weather station at President''s house (Soil Mois. Site)]

Record your data for each of the 3 sets of Infiltration measurements you make.

Sample Number [Select]

Water Level Change (Interval Depth):
Height above Ground Level (Upper Mark) [ ] mm
Height above Ground Level (Lower Mark) [ ] mm
Diameter of the Inner Ring: [ ] cm
Diameter of the Outer Ring: [ ] cm
Saturated Soil Water Content Below Rings (0 - 5 cm) at End of Experiment: [ ]

Enter the sequence of times below related to a single continuous infiltration experiment:

Start Time #1:
Hour: [00] **Minutes:** [ ] **Seconds:** [ ]
End Time #1:
Hour: [00] **Minutes:** [ ] **Seconds:** [ ]

Start Time #2:
Hour: [00] **Minutes:** [ ] **Seconds:** [ ]
End Time #2:
Hour: [00] **Minutes:** [ ] **Seconds:** [ ]

Start Time #3:
Hour: [00] **Minutes:** [ ] **Seconds:** [ ]
End Time #3:
Hour: [00] **Minutes:** [ ] **Seconds:** [ ]

Start Time #4:
Hour: [00] **Minutes:** [ ] **Seconds:** [ ]
End Time #4:
Hour: [00] **Minutes:** [ ] **Seconds:** [ ]

Start Time #5:
Hour: [00] **Minutes:** [ ] **Seconds:** [ ]

End Time #5:
Hour: 00 **Minutes:** **Seconds:**

Start Time #6:
Hour: 00 **Minutes:** **Seconds:**
End Time #6:
Hour: 00 **Minutes:** **Seconds:**

Start Time #7:
Hour: 00 **Minutes:** **Seconds:**
End Time #7:
Hour: 00 **Minutes:** **Seconds:**

Start Time #8:
Hour: 00 **Minutes:** **Seconds:**
End Time #8:
Hour: 00 **Minutes:** **Seconds:**

Start Time #9:
Hour: 00 **Minutes:** **Seconds:**
End Time #9:
Hour: 00 **Minutes:** **Seconds:**

Comments:

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